INVESTMENT REPORT 2024/25

INNOVATION INTEGRATION AND SIMPLIFICATION IN EUROPE

European Investment Bank | Group

Chapter 6

The European Union's green ambitions are driving its economic transformation

INVESTMENT REPORT 2024/25

INNOVATION INTEGRATION AND SIMPLIFICATION IN EUROPE

Chapter 6

The European Union's green ambitions are driving its economic transformation

European Investment Bank | Group

Investment Report 2024/2025: Innovation, integration and simplification in Europe

European Investment Bank
98 -100, boulevard Konrad Adenauer
L-2950 Luxembourg

This is a publication of the EIB Economics Department.
economics@eib.org
www.eib.org/economics

About the Economics Department
The mission of the EIB Economics Department is to provide economic analyses and studies to support the Bank in its operations and in the definition of its positioning, strategy and policy. The department and its team of economists is headed by Debora Revoltella, director of economics.

Disclaimer
The views expressed in this publication are those of the authors and do not necessarily reflect the position of the European Investment Bank.

For further information on the EIB's activities, please consult our website, www.eib.org.
You can also contact our InfoDesk, info@eib.org.

Published by the European Investment Bank.

Printed on FSC® Paper.

Chapter 6
The European Union's green ambitions are driving its economic transformation

Download the complete report:
https://www.eib.org/en/publications/20240354-investment-report-2024

Available as:

pdf: ISBN 978-92-861-5902-2 ISSN: 2599-8277

Table of contents

About the report

The annual EIB report on investment and investment finance is a product of the EIB Economics Department. The report provides a comprehensive overview of the developments and drivers of investment and investment finance in the European Union. It combines an analysis and understanding of key market trends and developments, with a thematic focus explored in greater depth. This year, the focus is Europe's ability to marshal the investment needed for the green transition and to support innovation. The report draws extensively on the results of the annual EIB Investment Survey (EIBIS) and the EIB Municipalities Survey, combining internal EIB analysis with contributions from leading experts in the field.

Main contributors to this year's report

Report director
Debora Revoltella

Report coordinators and reviewers
Laurent Maurin and Atanas Kolev

Authors
Chapter 1: Andrea Brasili, Jochen Schanz (lead authors), Tessa Bending, Giacomo Biolghini, Tran Thi Thu Huyen and Marcin Wolski. Dubravko Mihaljek (Box A). Koray Alper, Joana Conde, Pietro Dallari and Luca Gattini (Box B).

Chapter 2: Atanas Kolev (lead author), Andrea Brasili, Diana Lagravinese, Dubravko Mihaljek, Annamaria Tueske, Georg Weiers and Wouter van der Wielen.

Chapter 3: Laurent Maurin, Rozália Pál, Thi Thu Huyen Tran (lead authors), Frank Betz, Antonia Botsari, Chiara Fratto, Salome Gvetadze, Frank Lang, Jochen Schanz and Annamaria Tueske. Jose Miguel de Tertre (European Commission, Box A). Giorgio Presidente and Carlo Altomonte (Bocconi University, Box C). Matteo Gatti and Wouter van der Wielen (Box D).

Chapter 4: Michael Stemmer, Wouter van der Wielen (lead authors), Tessa Bending, Frank Betz, Marnix Bosch, Chiara Fratto, Jochen Schanz, Emily Sinnott, Annamaria Tueske, Marcin Wolski and Vaclav Zdarek. Nicholas Lazarou (European Commission, Joint Research Centre, Box A). Carolina Herrero (Box B).

Chapter 5: Julie Delanote, Péter Harasztosi, Christoph Weiss (lead authors), Marine Charlotte André, Ea Dumancic, Bertrand Magné and Julie Callaert (Expertise Centre for Research and Development Monitoring at KU Leuven University), Péter Fákó, Ramón Compañó and James Gavigan (European Commission, Joint Research Centre, Box A). Pierre Rousseaux (CREST, Box C).

Chapter 6: Fotios Kalantzis (lead author), Jan Eric Hagendorn, Bertrand Magné, Christos Mavrogiannis, Marcin Wolski and Vaclav Zdarek. Annamaria Tueske (Box C).

Acknowledgements

Ambra Boilini for research assistance.

Chapter 6

The European Union's green ambitions are driving its economic transformation

Europe's decarbonisation strategy sets out a bold vision of achieving carbon neutrality by 2050. This strategy is built on three pillars: carbon pricing through mechanisms like the EU Emissions Trading System; regulatory measures that mandate renewable energy adoption, emissions reductions and energy efficiency; and financial incentives, including subsidies and tax breaks, to foster green innovation. Together, these measures are driving the energy transition, promoting innovation and encouraging the transformation of energy-intensive industries, while also laying the groundwork for a competitive and sustainable green economy.

This framework is encouraging the rapid expansion of renewable electricity and the rise of electric mobility, leading to a drop in emissions in many industries. Clean energy has become the default choice for power utilities, driving broader electrification. However, progress is uneven. While efficiency gains and process improvements have contributed to emissions cuts in many sectors, industries such as chemicals, steel and cement – vital for manufacturing and construction – continue to face significant technological and financial challenges. Addressing these gaps will require targeted policies to accelerate innovation and bring economically viable clean solutions to market.

Strong and consistent environmental regulations play a pivotal role in overcoming these challenges. In sectors with stringent regulations, firms investing in energy efficiency benefit from significant gains in profitability, productivity and innovation. These improvements not only enhance competitiveness but also reinforce the European Union's climate ambitions, creating a positive feedback loop between sustainability and economic performance. Energy-efficient firms are also better equipped to navigate volatile energy prices and global competition. By contrast, weaker regulatory environments fail to provide sufficient incentives, particularly for energy-intensive industries. To ensure an inclusive transition, robust policies that provide clear direction could be paired with targeted support that encourages the transformation of businesses facing the greatest barriers to decarbonisation.

The success of the Emissions Trading System demonstrates the power of proactive policies to advance the transformation. By pricing carbon effectively, the system has spurred innovation and emissions reductions in key sectors. However, to ensure a balanced transformation, continuous adjustments must be made to guarantee leaders and laggards have the resources and incentives needed to make progress on their green goals.

While current policies focus on efforts to mitigate climate change, adaptation must not be overlooked. Climate risks are already affecting public and private entities, yet investments in resilience (such as improved infrastructure and other solutions) remain limited. Combining adaptation measures with emissions reductions will not only guard against the most direct impact of climate change, but also ensure the EU economy remains resilient in the face of future challenges.

Introduction

This chapter reviews Europe's progress in reducing emissions and transitioning sectors to greener and more sustainable practices. It looks at the diverging global patterns emerging in decarbonisation, increasing geopolitical tensions and widespread concerns about European competitiveness. It consists of three sections and four boxes.

The first section examines long-term trends in the carbon emissions of specific sectors, as well as the key drivers and deployment of climate mitigation technologies. It emphasises the achievements made to date and shows that they vary from sector to sector. Decarbonisation often comes at the cost of reduced production, especially in highly energy-intensive industries. The section also provides evidence of the rapid transformation of EU electricity production to clean energy – a critical enabler of the green transition. A box looks at the impact of new EU rules for corporate sustainability.

The second section focuses on disparities in how EU firms use energy and emit carbon, and how those disparities affect their overall performance. Using data from the EIB Investment Survey (EIBIS) and the Emissions Trading System, the section identifies factors distinguishing transition leaders from laggards, including operational efficiency, technological adoption, financial constraints and regional or sectoral differences. It examines the relationship between energy efficiency and firm performance for profitability, productivity, innovation and employment. It contains a box explaining meta-stochastic frontier analysis (the methodology used to evaluate firms' energy efficiency).

The section also shows that combining encouragement for green investment with stricter climate regulation often results in greater returns for firms that invest in energy efficiency. These companies tend to have higher profitability, productivity, innovation and employment. In environments with weaker regulation, however, firms in energy-intensive industries that invest in energy efficiency do not have higher returns than those that do not invest, which weakens the rationale for energy efficiency efforts. A third box summarises the findings of a study on the regulatory environment and access to finance as major forces driving energy-efficiency investment. A fourth box focuses on leaders and laggards in sectors covered by the Emissions Trading System.

The third section addresses climate adaptation efforts by firms and municipalities. It identifies shared challenges, unique barriers and opportunities to work together as firms and local governments respond to the growing effects of climate change.

By integrating insights from these three perspectives, this chapter provides a comprehensive overview of Europe's decarbonisation journey, highlighting successes and ongoing challenges as it moves to a sustainable and competitive future.

Europe's emissions-reduction progress masks sector differences

This section provides an overview of the European Union's transition to a sustainable economy, focusing on the progress made in emissions reductions, the evolution of EU energy markets, advances in the deployment of green technologies and an assessment of cleantech innovation.

Europe's decarbonisation continues amid global climate uncertainty

The global political environment may be casting a long shadow over our collective ability to maintain temperatures well below 2° Celsius, but Europe's direction of travel is clear. The European Union's Copernicus Climate Change Service (C3S) said that 2024 was the hottest year on record. Damaging

extreme weather events are being seen across the world, but there is a lack of global consensus on the urgency of climate change. Against this backdrop, the newly appointed European Commission has reinforced its ambition to reduce net greenhouse gas emissions at least 55% by 2030 (relative to 1990 levels), and to reach climate neutrality by the middle of the century (von der Leyen, 2024).

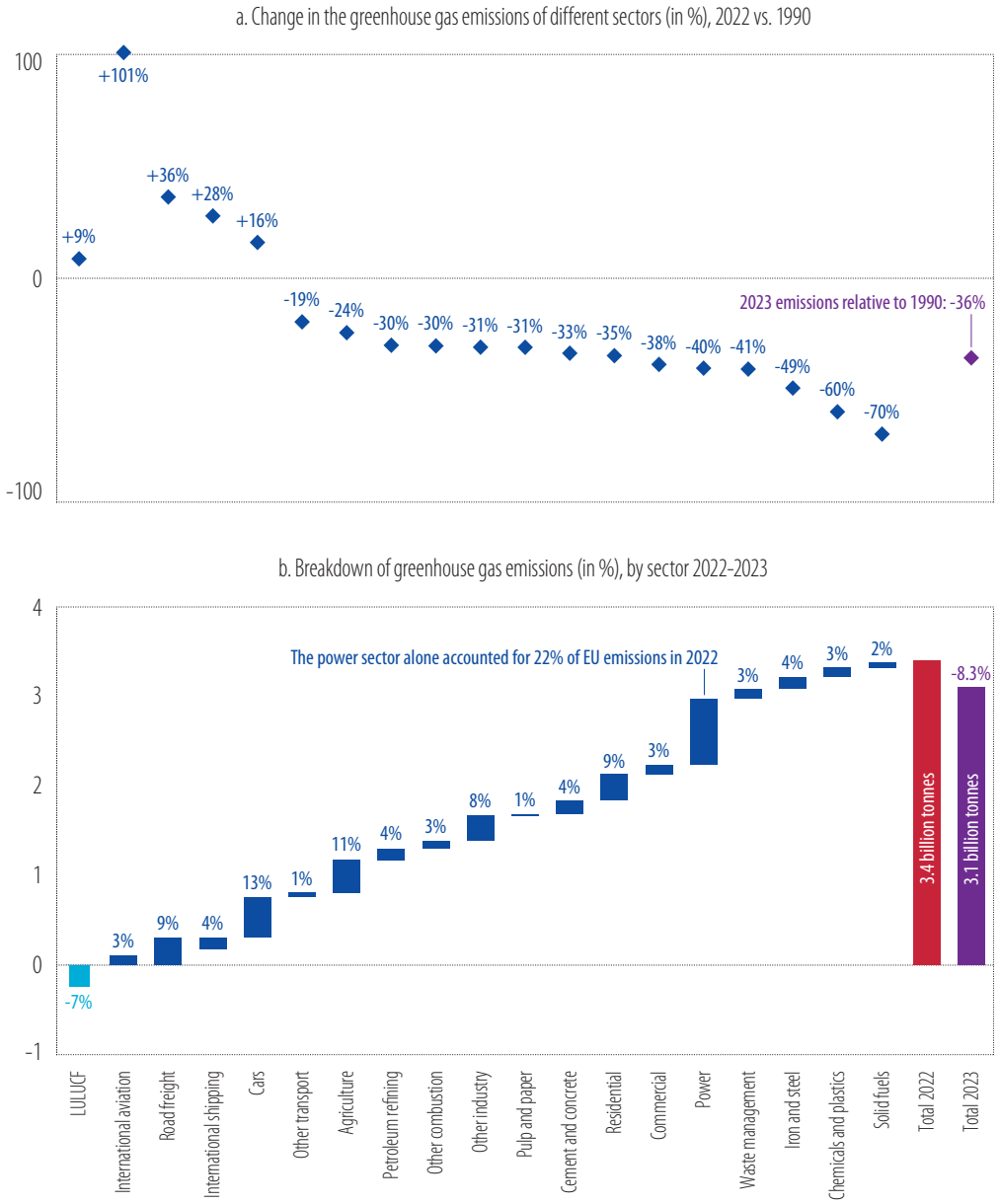
Halfway through the United Nations' Decade for Action, the European Union's decarbonisation journey is very much underway, with the groundwork being laid for a new model of economic growth that will help preserve its long-term competitiveness. The EU economy has grown by almost 170% in per capita terms since 1990, and EU net greenhouse emissions are now 37% below 1990 levels (an average reduction of 1.2% a year). In 2023 alone, emissions fell by 8.3% compared to the previous year. Looking forward, the annual emissions-reduction rate needs to rise significantly to bring harmful emissions down 90% by 2040, relative to 1990 levels – as proposed by the EU 2040 assessment (European Commission, 2024b) – and to reach full decarbonisation a decade later. To meet this objective, policies and actions must follow a coherent plan and be implemented with seamless coordination. Europe must also apply all available solutions without favouring any specific technology. If successfully completed, such an approach could actually improve Europe's economic prospects (Draghi, 2024).

The transformation of power production is driving Europe's green transition. Accounting for almost 20% of total greenhouse gas emissions, the power sector is the continent's top emitter (Figure 1). However, it has undergone a rapid transformation, with emissions falling by 59% in 2024, compared to 1990 levels. This trend accelerated in recent years, with a 24% decline in 2023, followed by a further 13% drop in 2024 (Eurelectric, 2024). Behind this trend is a substantial reduction in the carbon intensity and energy intensity (Figure 2) of power production, as coal was gradually replaced by gas and competitive renewable energy sources substantially increased since 2010. The trend has also benefited from continued reliance on nuclear power, which now covers about one-quarter of EU electricity needs (Figure 3).

Industrial activities generate similar volumes of emissions to those of the power sector, but improvements are more incremental and mainly result from optimised processes and energy efficiency gains (European Commission, 2024a). Energy efficiency investment has become a key priority in many sectors, but in some hard-to-abate domains, decarbonisation is mostly being achieved by scaling back activities. The increase in the price of EU Emissions Trading System allowances is forcing companies to transform, while the switch to less emissions-intensive technologies is not always economically viable. As such, reducing emissions is mostly done by reducing production or by reducing the carbon intensity of that production (see Chapter 3, Figure 2). Chemicals and steel have cut emissions the most among hard-to-abate sectors, more than halving their emissions since 1990 (European Chemical Industry Council (CEFIC), 2023).

Industries focused on mobility and shipping are lagging behind on decarbonisation. Progress in the adoption of electric vehicles or other low-emission transport has not yet translated into sizeable carbon reductions, and is moving too slowly to offset the growing number of conventional cars on the road (Figure 2). Similarly, the benefits of fuel efficiency improvements barely compensate for increased freight activity, leaving current emissions close to their 2010 levels. In the aviation sector, a revision of the EU Emissions Trading System Directive will lead to the full auctioning of allowances and will enhance support for eligible alternative aviation fuels that are financed by the system. The carbon charge is still not enough to close the price gap between conventional fossil fuels and eligible alternative aviation fuels. Despite global initiatives to cut emissions in the shipping industry (Getting to Zero Coalition, 2021), which is the backbone of global trade, the absence of viable alternatives to marine diesel oil means that a notable cut in emissions is not realistically possible before 2030.

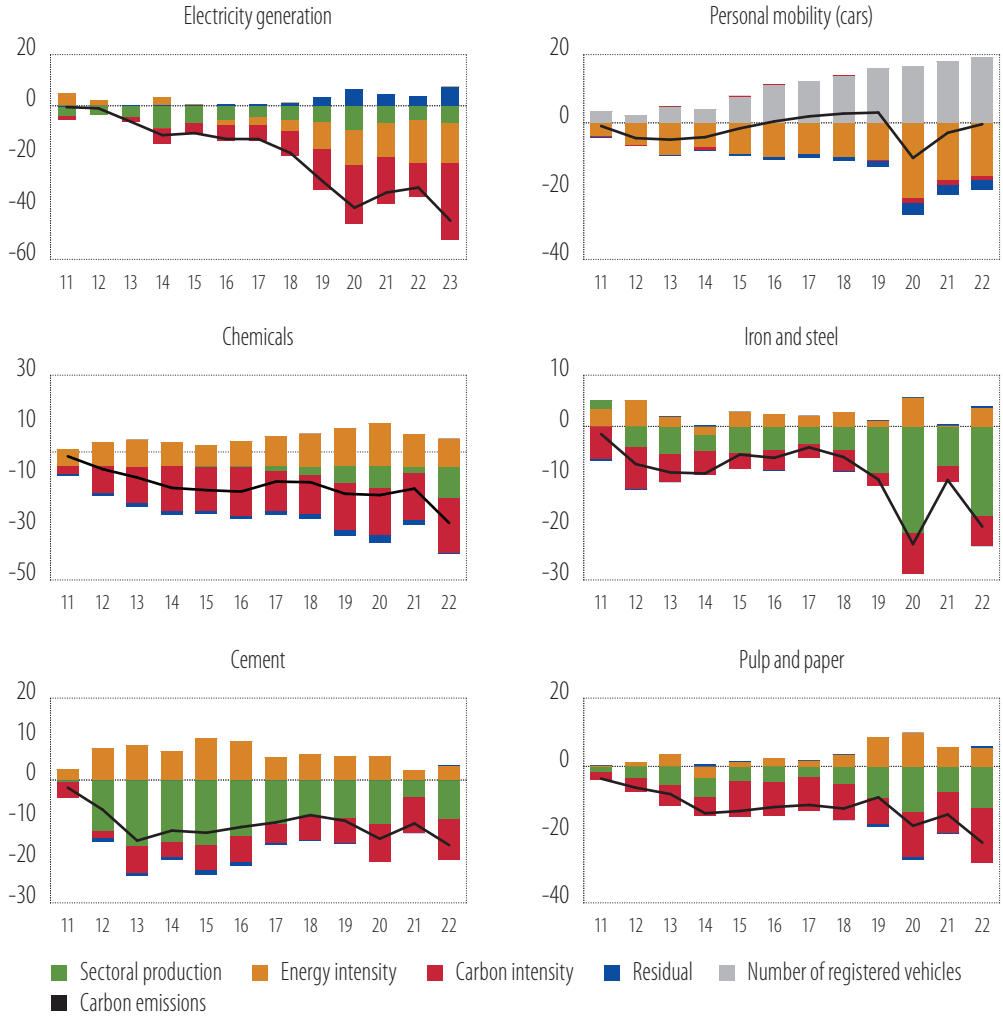
Figure 1
Europe is making significant progress in cutting emissions



Source: *European Environment Agency (EEA).*
Note: *LULUCF stands for land use, land-use change and forestry.*

Figure 2

Change in the composition of carbon emissions (in %) **since 2010, by sector**



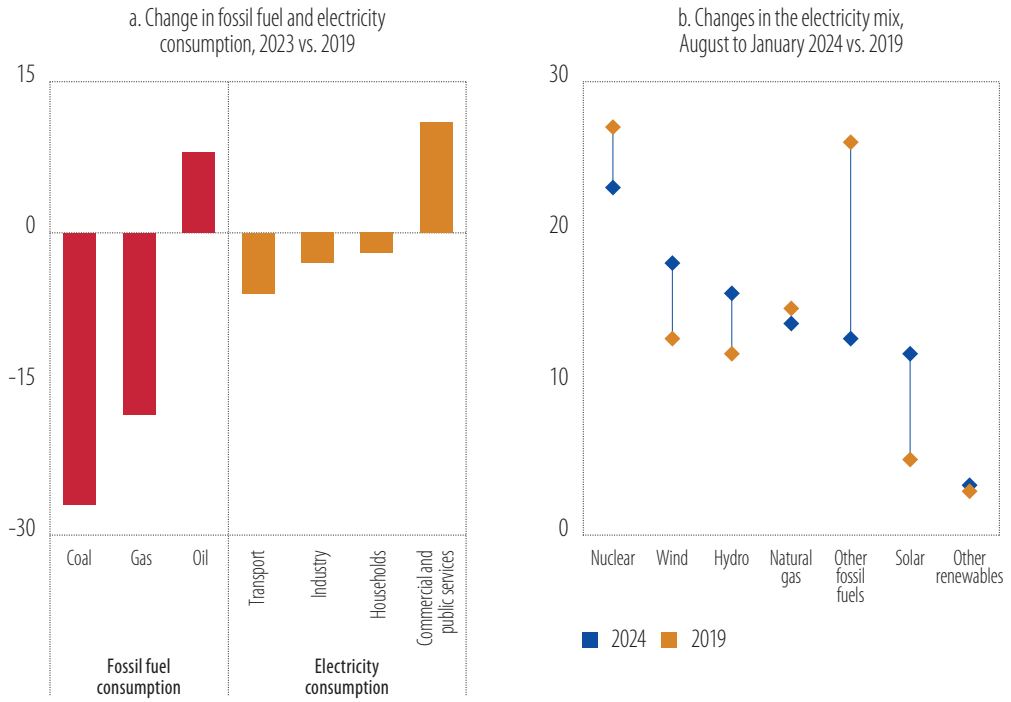
Source: *Eurostat, EEA 2024.*
Note: *The decomposition analysis uses the Kaya identity, which gives rise to residual components unlike approaches using a logarithmic mean divisia index (LMDI).*

Clean energy is gaining ground

Fossil fuels are losing their prominence – a tangible sign of the transition unfolding in Europe. The use of fossil fuel for electricity generation dropped a record 19% in 2023 (Ember, 2024). Coal supplied a mere 12% of electricity to European customers (below levels seen during the COVID-19 pandemic in 2020), pushed out of the mix by expanded renewable capacities and a resumption of nuclear power. Coal use slumped in 23 European countries from January to August 2023, compared to the prior year, while the European Union-wide figure fell by 27% from 2019 to 2023 (Figure 3). There has been a clear drop in oil use in countries such as the Netherlands and Sweden, which are among Europe's most dynamic markets for electric cars. Natural gas is also losing ground due to the strong uptake of clean

electricity sources – about half (48%) of electricity in Europe was generated from renewable sources in 2024. Solar capacities have expanded rapidly (by 25% in 2023), and are on track to meet their 2030 target (600 GW of newly installed capacity by 2030). Capacity increases are particularly notable in Germany and Italy. Solar capacity rose 15% in Germany and 45% in Italy in the first half of 2024 (International Energy Agency (IEA), 2024a). However, end-use applications of renewable energy are progressing more slowly. In 2022, 23% of energy needs were met with renewable sources, still far from the 42.5% objective set for 2030 (Figure 4).

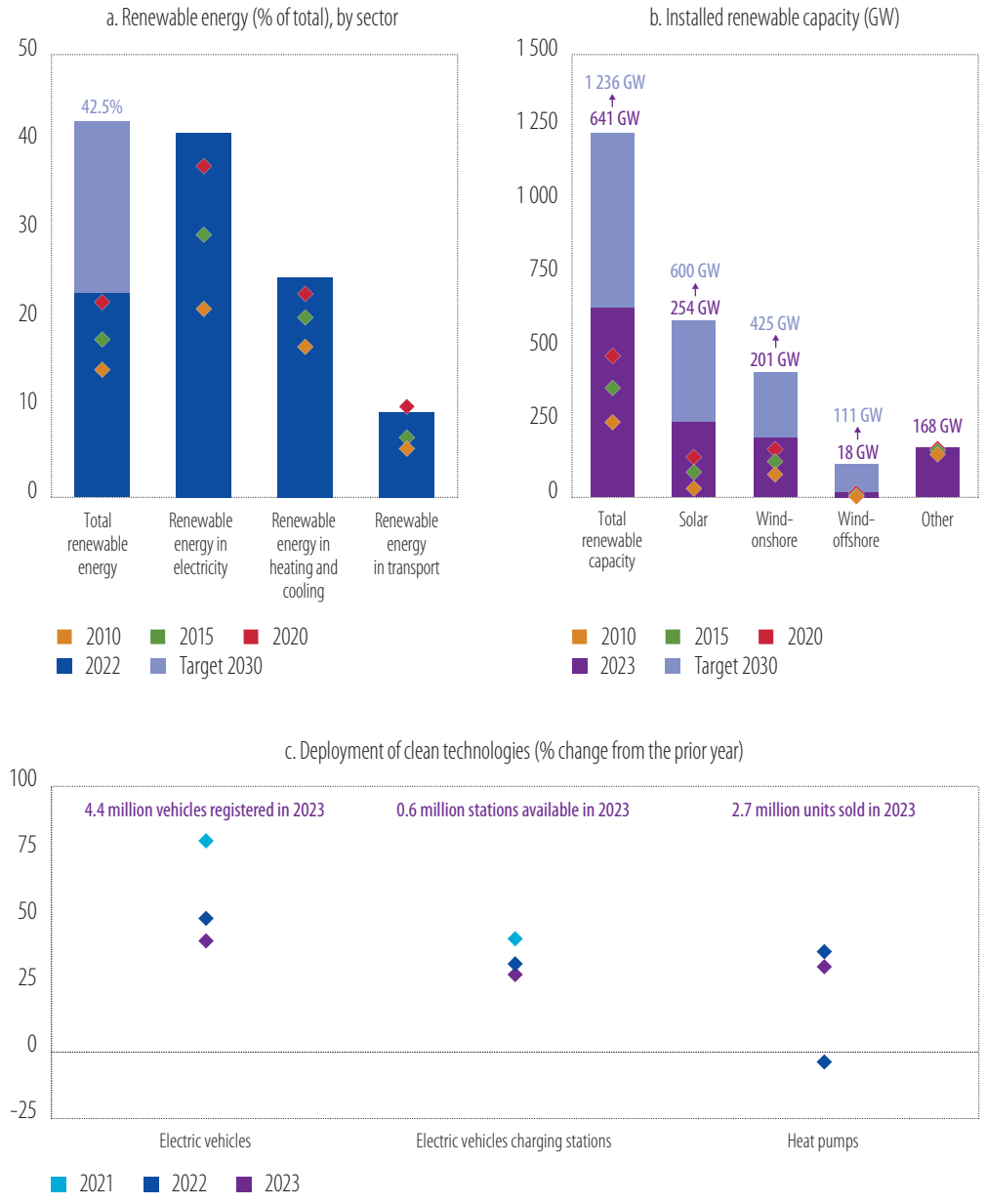
Figure 3
Changes in the energy supply and demand (in %)



Source: *Eurostat.*

Despite their potential for cutting emissions, the markets for electric vehicles and heat pumps are showing signs of weakness. Electric vehicle adoption in Europe is levelling off after the phase-out of public incentives in Germany and despite a 6% increase in electric vehicle sales in other EU countries (IEA, 2024a). In 2024, the heat pump market also experienced a strong correction as natural gas prices returned to pre-crisis levels, thereby discouraging household spending on energy-efficient devices.

Figure 4
Renewable energy deployment



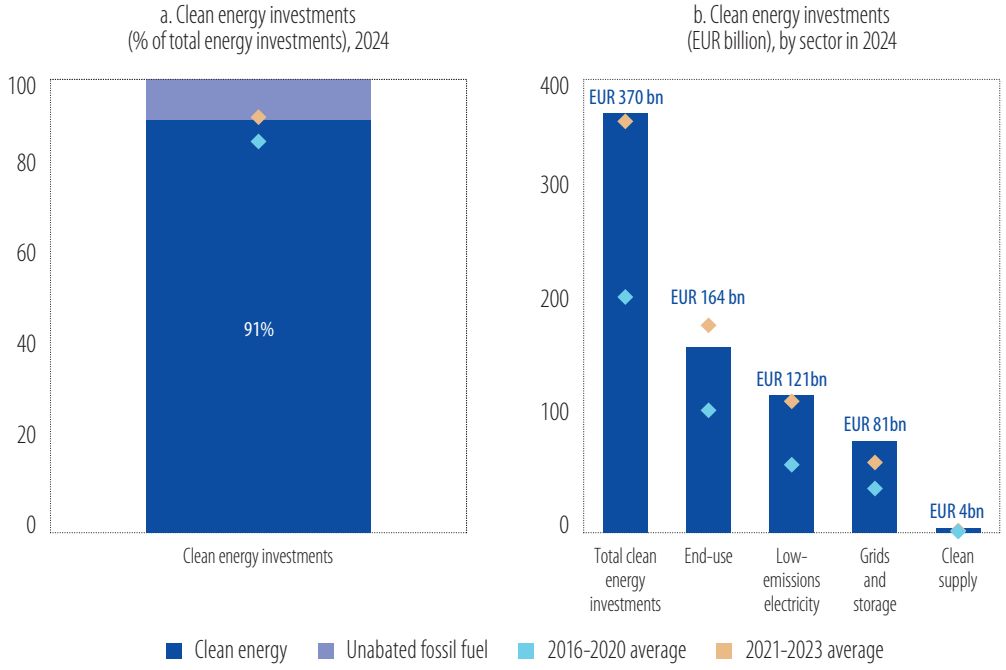
Source: *European Commission's Directorate-General for Energy, International Energy Agency (IEA), International Renewable Energy Agency, Ember, European Heat Pump Association, European Automobile Manufacturers' Association, Alternative Fuels Infrastructure Regulation.*

Clean energy investments remain dynamic despite challenges

Clean energy investments lost some of their momentum after the sharp rise seen until 2020, but remain broadly in line with the European Union's energy and climate goals. Investments in oil and gas production and storage exceeded EUR 30 billion in 2024, with about EUR 7 billion invested in liquefied natural gas to offset the shortage in Russian supplies and secure supplies following the energy crisis. Clean energy investments have remained very attractive in Europe, even in 2023 when supply chain constraints and inflationary pressure drove up financing costs. Europe's clear commitments to the green transition have resulted in clean energy investments that account for over 90% of total energy investments. Early estimates from the International Energy Agency (IEA) indicate that clean energy investments hovered around EUR 370 billion in 2024 (Figure 5). Low-emission electricity and grid developments account for more than half of clean energy investments. Power network extensions and digitalisation are now seen as a priority for enabling end-use electrification (industries, transport and heating) and more power market integration (Draghi, 2024).

Outside of power generation, the switch to clean energy is largely concentrated in a few segments, mainly electric vehicles and heat pumps. These areas have seen notable growth driven by strong consumer demand and supportive policy frameworks. However, despite some progress, there is little indication that a marked shift to faster and greater emissions reductions is on the way. Breakthrough innovations are still needed to drive faster and more widespread emissions reductions in a broader range of industries. Without addressing these investment hurdles and scaling up solutions in hard-to-abate sectors, the overall pace of Europe's clean energy transformation may remain constrained.

Figure 5
Clean energy investment trends



Source: *IEA.*

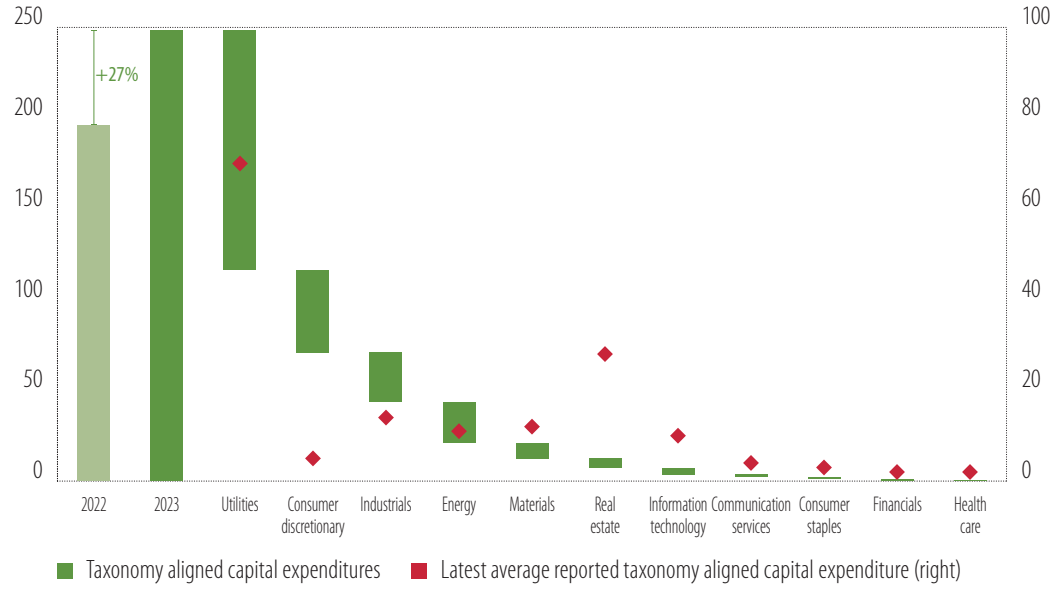
Disclosures of large EU firms' investments in green activities shed some new light on investor appetite for the green transition. The EU sustainable finance framework – now in its second year of implementation – requires firms to disclose their sustainability efforts. These requirements are showing encouraging signs of uptake by companies (European Commission, 2024c). In 2023, some 1 500 companies representing a total of EUR 6.8 trillion in market capitalisation reported capital expenditure

earmarked as green or aligned with the EU taxonomy for sustainable activities (Goldman Sachs, 2024). The majority of EU taxonomy-aligned investments have been declared in France and Germany, where domestic policy, regulatory frameworks and access to capital support disclosures.

Green investments are concentrated in a handful of industries that are key to climate change mitigation. The first batches of disclosures confirm that capital is flowing to clean energy in the ways highlighted above. In total, about EUR 250 billion of green capital expenditure was reported in 2023, a 27% increase vs. 2022 (Figure 5). Key reporting sectors include power utilities and network operators, which are responsible for more than half of reported capital expenditure, and companies involved in clean mobility (such as electric motor manufacturing and automobile assembly), the manufacturing of energy-efficient equipment for buildings and industries and, to a lesser extent, the construction of new buildings.

Figure 6

Taxonomy alignment of capital expenditure (left axis: EUR billion; right axis: % of total capital expenditure)**, by sector**



Source: Bloomberg, Goldman Sachs (2024).

Box A

Corporate sustainability as a driver of green transformation

A sustainable and competitive European economy must also be transparent and accountable, especially when it comes to pricing green assets and risks. The European Union has taken a significant step forward by introducing a framework for corporate sustainability reporting underpinned by the Corporate Sustainability Reporting Directive (CSRD). This transformative initiative aims to equip investors, consumers and civil society with reliable and consistent data on companies' environmental and social impact, fostering the creation of a trusted and liquid market for sustainable investments.

Sustainability reporting serves investors by enabling them to identify green assets and manage risks. It also empowers companies to assess their own exposure to environmental and social risks, and signals these risks to potential investors and financiers. However, the implementation of the European Union's ambitious reporting framework presents opportunities and challenges.

The EU sustainability reporting framework: Objectives and challenges

The CSRD builds upon earlier initiatives such as the Non-Financial Reporting Directive and introduces stricter requirements under the European Sustainability Reporting Standards. Approximately 50 000 companies – including large firms, listed small and medium-sized enterprises (SMEs), and non-EU companies with securities on EU-regulated markets – are required to report on their sustainability performance, starting with 2024 data. These reports must cover technical screening criteria for six environmental objectives under the EU taxonomy, including climate mitigation and adaptation.

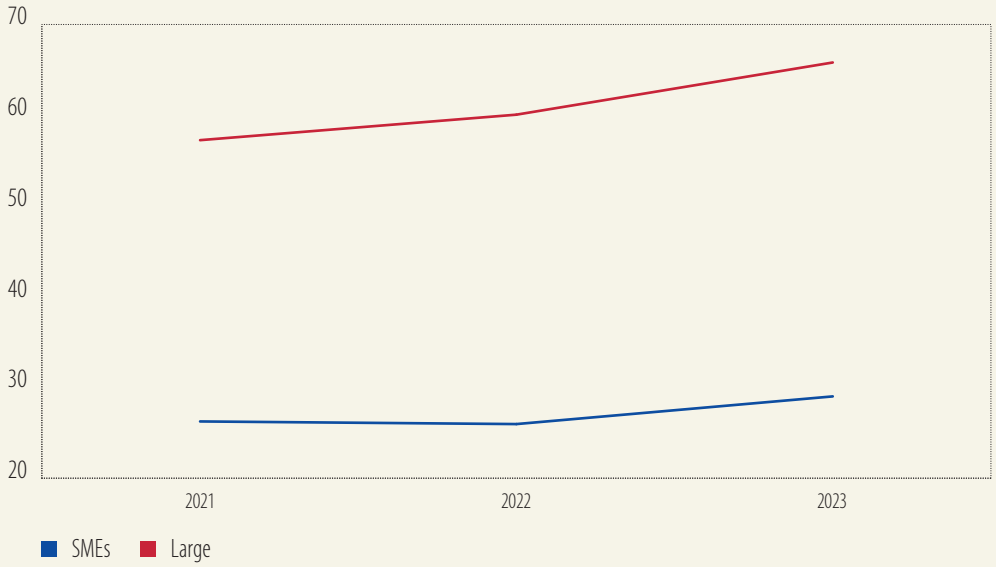
However, concerns have been raised about the complexity of complying with these rules. Companies are required to document transition plans, conduct double materiality assessments (which look at the broader impact of climate change on the operating environment or society as whole) and report up to 1 200 data points. The associated administrative costs are significant, particularly for smaller firms, with recurring annual costs estimated to be EUR 240 000 per company (European Financial Reporting Advisory Group (EFRAG), 2022). Smaller firms were only supposed to be affected if they were listed publicly, but some of them are finding themselves drawn into regulatory reporting, as large companies often need certifications from their suppliers.

Setting and reporting climate targets for EU firms: Insights from the EIBIS

Data from the EIBIS sheds light on EU firms' climate reporting readiness. Figure A.1 shows that some 65% of large EU firms were already setting and reporting targets in 2023, up from 57% in 2021. The share of SMEs is much lower, at 29%, with these businesses not directly required to report this information.

Figure A.1

Share of firms (in %) **setting climate targets, by firm size**

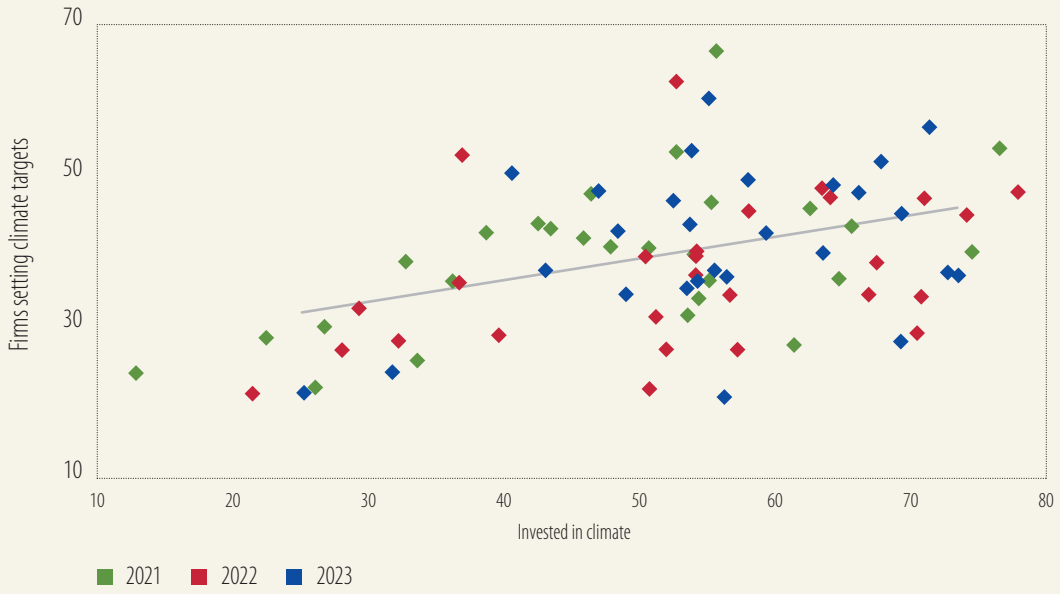


Source: *EIB staff calculations based on EIBIS 2022-2024*

EIBIS data highlights a positive link between setting climate targets and investing in mitigation and adaptation. Figure A.2 shows that from 2021 to 2023, the share of firms investing in climate-related initiatives has increased, correlating with a rise in the percentage of firms setting climate targets.

Figure A.2

Comparison of firms (in %) **investing in climate measures and those setting climate targets, by year**



Source: EIB staff calculations based on EIBIS 2022-2024. The diamonds refer to the 27 EU countries.

Working towards a balanced and effective sustainability framework

The CSRD and related EU regulations are crucial to nurturing green transformation. To implement these initiatives in the current environment, however, regulators need to strike a balance between the positive effects on transparency, accountability and practicality and the potentially excessive burden these regulations pose to firms, particularly SMEs. The European Commission has therefore proposed an omnibus package for 2025 that aims to simplify and streamline the regulatory framework, while preserving the long-term objectives of the measures.

As the EIBIS data shows, the growing commitment of firms to setting climate targets and investing in climate action signals a promising shift. By addressing the unique challenges faced by firms and supporting their green endeavours, the European Union can foster a more inclusive and competitive market.

Clean energy innovation needs to ramp up and overcome technological barriers

Innovation is critical for the transition, because the lack of commercially viable alternatives to polluting activities and production processes often blocks decarbonisation. A vast array of technologies is required to radically transform the way energy is produced and consumed. According to the IEA, about 600 technologies are needed to make supply chains fully green, with various stages of development.[1,2] Some are mature and competitive, such as solutions for power generation and building renovation. Figure 6 provides a summary of the number of technologies involved in various supply chains that are vital for the decarbonisation of industry, suggesting that in most cases technologies are still far from commercialisation and large-scale deployment.

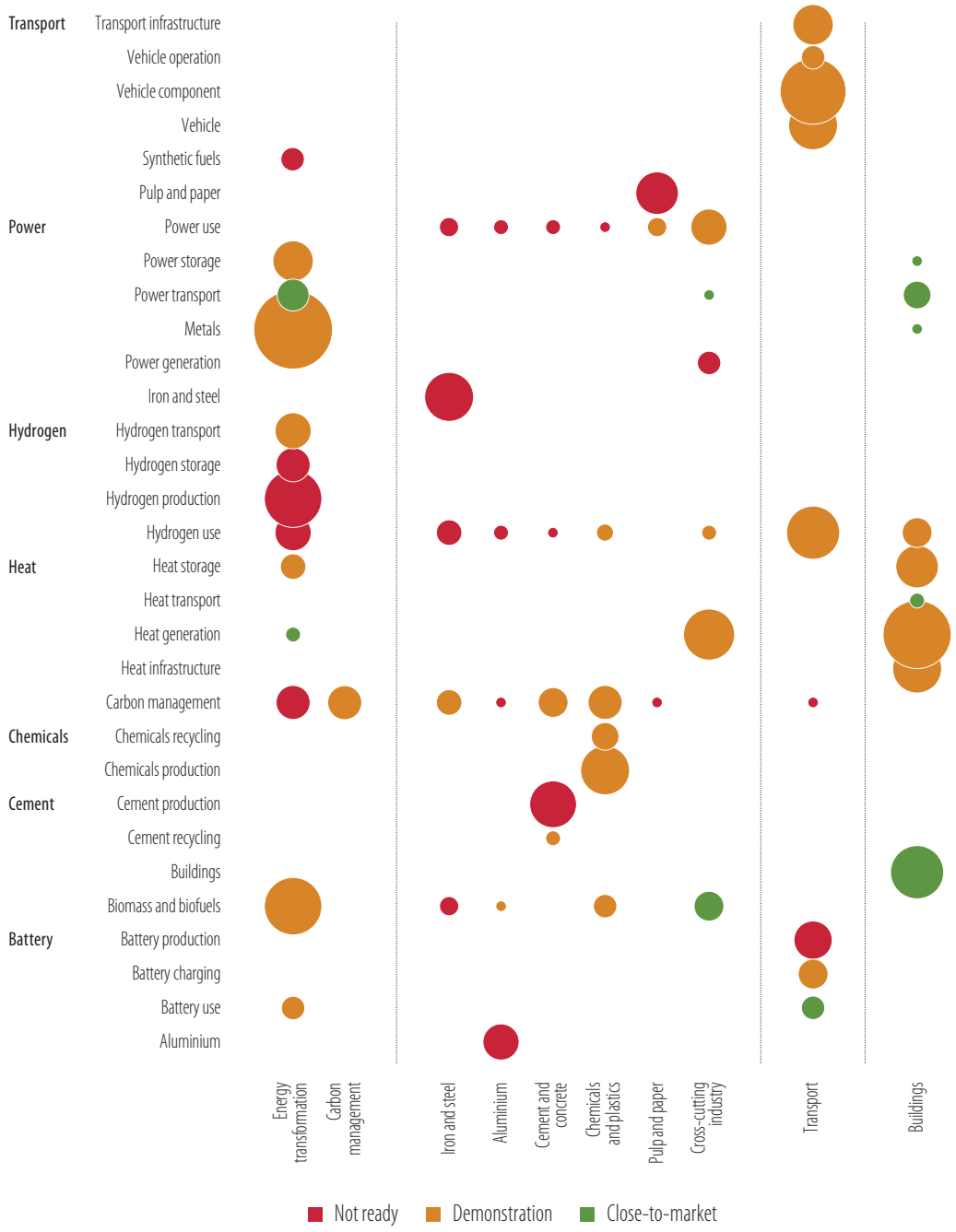
A strategic and coordinated approach to innovation is crucial. Technologies involved in energy transformation (which often involve electrons or molecules) have complex supply chains, namely the production and storage of clean hydrogen and carbon capture and storage technologies. Bolstering innovation and bringing these technologies closer to market is a critical step towards electrification and the decarbonisation of hard-to-abate activities. The production of greener materials with lower carbon footprints (such as green steel, green cement, green aluminium and low-emission chemical products) will eventually enable more sustainable mobility, freight, shipping, construction and agricultural practices. However, major technological breakthroughs for most raw commodities are not expected before the mid-2030s (Mission Possible Partnership (MPP), 2022; MPP, 2023).

The right business environment and financial frameworks will help European innovators overcome technological hurdles. However, EU firms have difficulty commercialising innovative products (EIB, 2024). The lack of a clear business case compounded by supply chain constraints and high energy and carbon abatement costs often hinders industrial transformations and discourages investors (Draghi, 2024). These transformations must come with upgraded infrastructure such as more integrated power, distribution and transport networks, a boost in demand for sustainable products, more effective and targeted public policies and easier access to capital for firms developing disruptive technologies (World Economic Forum (WEF), 2023).

1 The IEA Clean Energy Technology Guide is an interactive database maintained by the International Energy Agency containing information about nearly 600 individual technology designs and components across the whole energy system that can contribute to achieving net zero emissions.

2 Technologies are characterised by their technology readiness levels. These track the development of products from basic scientific discovery, through demonstration in various settings, up to technology validation and mass-scale deployment.

Figure 7
Maturity of cleantech supply chains, by end-use sector



Source: *IEA (2024c), ETP Clean Energy Technology Guide.*
Note: *The figure brings together the various supply chains (listed on the vertical axis) that are indispensable to the decarbonisation of energy end-use (listed on the horizontal axis). Bubble sizes indicate the number of technologies involved in each clean energy supply chain. Colours refer to average readiness levels of technologies (TRLs). TRLs 1-3 are labelled as "not ready," while technologies with TRLs ranging 6 to 9 are deemed "close-to-market." Colours refer to the level of readiness of each pertinent technology for a given end-use sector.*

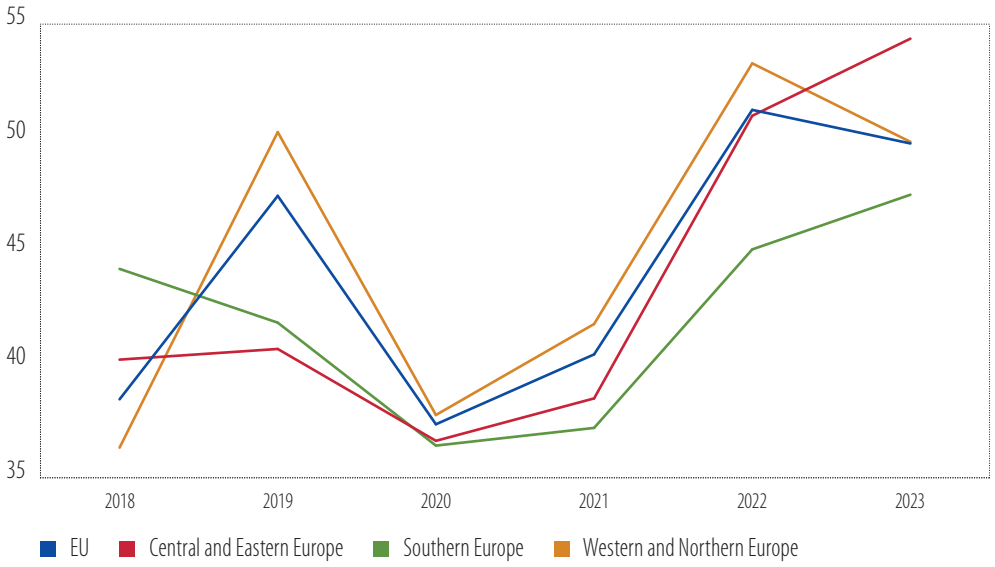
Regulation and energy efficiency as a strategic lever for transformation

This section examines the energy efficiency performance of European firms using data from the EIBIS. It assesses deviations from the most energy efficient practices and identifies whether these gaps stem from operational inefficiencies or a reliance on less advanced technologies. The analysis explores the drivers and barriers shaping energy efficiency in different regions and sectors and estimates the returns on energy efficiency investments for profitability, productivity, innovation and employment. This work can inform targeted strategies to close energy efficiency gaps, addressing key barriers and unlocking new ways for the EU economy to grow equitably and sustainably.

EU firms respond to rising energy costs with efficiency measures

Energy efficiency has become a cornerstone of the European Union's efforts to reduce carbon emissions and enhance economic competitiveness. Figure 8 highlights the evolution of firms investing in energy efficiency in the European Union and across its major regions: Central Europe, Western and Northern Europe and Southern Europe. Energy efficiency investments recovered in 2023 after declining in 2020, likely because of the COVID-19 pandemic, surpassing pre-pandemic levels in most European regions. Investment by Western and Northern European companies increased the most sharply in 2019 and reached the highest share of firms by 2023, despite declining in 2020. Similarly, Southern European firms steadily improved from 2020, reaching the highest share of firms investing in energy efficiency in 2023. Firms in Central and Eastern Europe recorded a more gradual rise, but eventually exceeded the levels seen in the other two regions.

Figure 8
Firms investing in energy efficiency (in %)



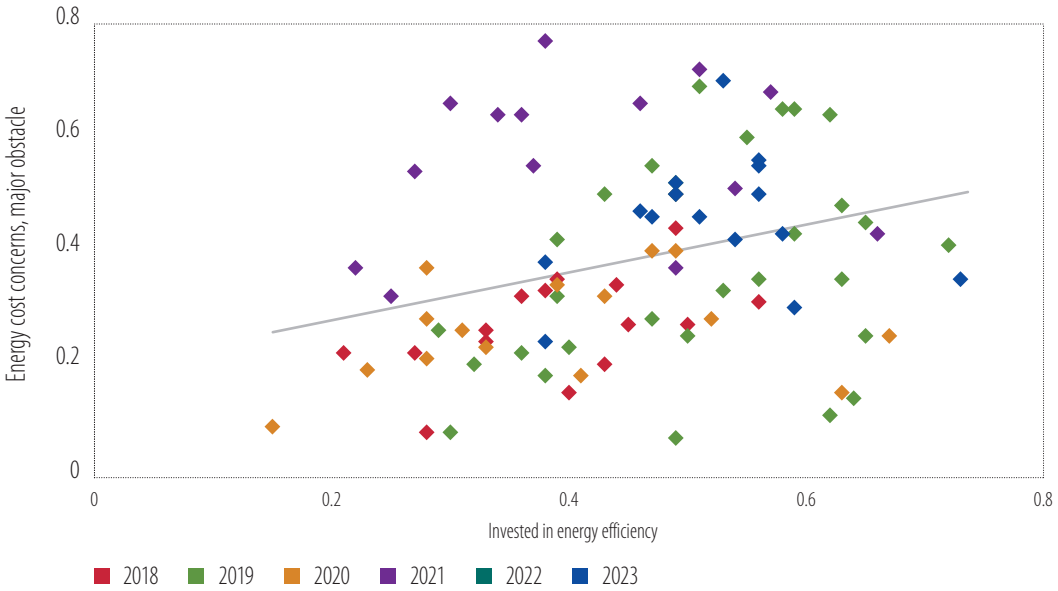
Source: *EIBIS 2018-2024.*
Question: *What proportion of the total investment in the last financial year was primarily for measures to improve energy efficiency in your organisation?*

Firms have been expanding investment in energy efficiency in recent years as concerns about rising energy costs grow. Figure 9 illustrates a sector-adjusted relationship between the share of firms reporting energy costs as a major obstacle to investment and the share investing in energy efficiency from 2018 to 2023. A positive correlation emerges, suggesting that firms are increasingly likely to invest

in energy efficiency as cost concerns rise. A temporal pattern is evident, with earlier years like 2018 and 2019 showing a lower share of firms saying they were concerned about energy costs, and subsequently lower energy efficiency investments, while 2022 and 2023 have higher values in both areas.

Figure 9

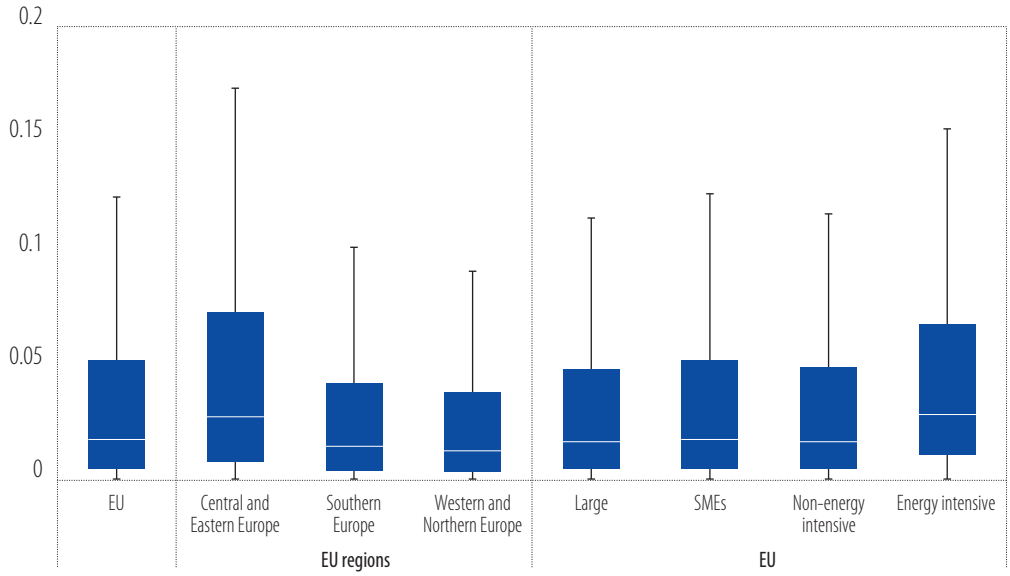
The share of firms (in %) **that have invested in energy efficiency compared with those saying energy costs are a major obstacle to investment, 2018-2022**



Source: *EIBIS 2018-2024.*
Question: *What proportion of the total investment in the last financial year was primarily for measures to improve energy efficiency in your organisation? Thinking about your investment activities, to what extent is energy cost a major, minor or not an obstacle?*

Figure 10

Energy spending as a share of turnover (in %)**, by region, size and energy intensity**



Source: *EIBIS 2023-2024.*
Question: *How much did your company spend on energy in the last financial year?*

This variability is evident across regions, firm sizes and sectors, with Central Europe, small and medium firms and energy-intensive firms experiencing the highest energy costs relative to turnover. At the EU level, firms show moderate variability in energy spending, as indicated by the range and distribution in Figure 10. However, noticeable differences emerge when examining regions. Central Europe exhibits the highest variability and median energy spending, suggesting that energy costs have had a greater impact, while Southern and Western and Northern Europe show lower medians and narrower ranges. For firm size categories, small and medium-sized enterprises (SMEs) tend to have slightly higher ratios for energy costs as a share of turnover and greater variability than large firms, reflecting their limited ability to absorb rising energy costs. Large firms, on the other hand, have more stable ratios, likely because they benefit from economies of scale and better energy management practices. Differences can also be observed between energy-intensive and non-energy-intensive firms. Energy-intensive firms consistently allocate a much larger proportion of their turnover to energy spending, as reflected by higher medians and broader interquartile ranges. This shows the significant financial strain faced by energy-intensive sectors because of their reliance on energy and exposure to price fluctuations.

Box B

Evaluating energy efficiency using meta-stochastic frontier analysis

This box outlines the use of meta-stochastic frontier analysis to evaluate the firms' energy efficiency, by comparing energy spending relative to output and other inputs (capital and labour) in different sectors based on the EIBIS. The parametric meta-stochastic frontier analysis approach is more robust than non-parametric techniques (such as data envelopment analysis or descriptive indicators such as energy intensity) for assessing the efficiency of resource utilisation, particularly energy, in different sectors employing varying technologies.

Conceptual framework

Stochastic frontier analysis measures firm efficiency by comparing actual performance to the "frontier" (the maximum possible output achievable given the inputs). Meta-stochastic frontier analysis extends this framework by incorporating a meta-frontier (combining all sector frontiers) setting a benchmark for the best performance across all sectors (in this section), regardless of the technology used. This enables inefficiency to be broken down into two components: a) sector inefficiency, which is assessed relative to the sector-specific frontier; and b) the technological gap, which is assessed relative to the meta-frontier.

In sum, the meta-stochastic frontier analysis methodology provides three key efficiency measures:

- **Sector technical factor energy efficiency (within-sector TFEE):** This indicates a firm's efficiency relative to its sector's frontier, which represents the firm's operational efficiency.
- **Technology gap ratio (TGR):** This captures the gap between the sector frontier and the meta-frontier, reflecting the sector's relative technological advancement.
- **Meta-frontier (meta):** This reflects overall efficiency relative to the meta-frontier, defined as the product of sector technical factor energy efficiency and the technology gap ratio.

Methodological steps

The analysis assumes a Cobb-Douglas production function, following the methodological approach of Honma and Hu (2018), and implements an input distance function to quantify firms' energy efficiency performance. The Cobb-Douglas functional form simplifies the estimation process while remaining flexible enough to analyse energy efficiency. The function is homogeneous of degree one in inputs, that is, $f(y, \mu^*x)=\mu^*f(x,y)$, $\mu>0$.

Specifically, the current analysis employs a two-step approach to estimate sector technical factor energy efficiency and the technology gap ratio using stochastic frontier analysis, overcoming the limitations of earlier methods. This ensures consistency in efficiency measurement while addressing technology heterogeneity between sectors.

- **Step 1:** Sector frontier estimation

The sector input distance function for each sector s is estimated using the following stochastic frontier analysis model:

$$-\ln x_{N,i,s,t} = \ln f(y, x_{i,s,t}/x_{N,i,s,t}, \beta) + v - u^{+} \quad (1)$$

Where *y* is the value added of firm *i*, in sector *s* and year *t*, $x_{N,i,s,t}$ is the energy spending, $x_{i,s,t}$ are the other two input factors, labour and capital, *v* is a two-sided error term satisfying the classical assumptions and *u* is an on-sided random variable representing technical inefficiency, and β is a vector of technological parameters. All factors have been normalised by turnover, and energy spending has been deflated by the energy price index to isolate changes in spending due to quantity changes rather than price fluctuations. Similarly, all the other variables have been deflated by the consumer price index to reflect overall economic conditions and general inflationary trends. In addition, the stochastic frontier analysis model controls for any country and size-specific invariant factors.

The within-sector technical factor energy efficiency is estimated from: Within-sector TFEE=1/exp(u+)

- **Step 2:** Meta-frontier estimation

The technology gap ratio is then estimated by considering the distance of the actual energy spending over turnover from the optimal level based on the estimated sector technical factor energy efficiency, which is the dependent variable. In other words, this variable is the product of the sector technical factor energy efficiency and the actual level. The new estimated technical efficiency will reflect the technology gap ratio based on a pooled estimation with yearly effects following exactly the same process as in step 1.

By combining the estimated within-sector sector technical factor energy efficiency and technology gap ratio, the meta can be obtained as follows:

$$\text{Meta}_{ist} = \text{Within-sector TFEE}_{ist} * \text{TGR}_{ist}$$

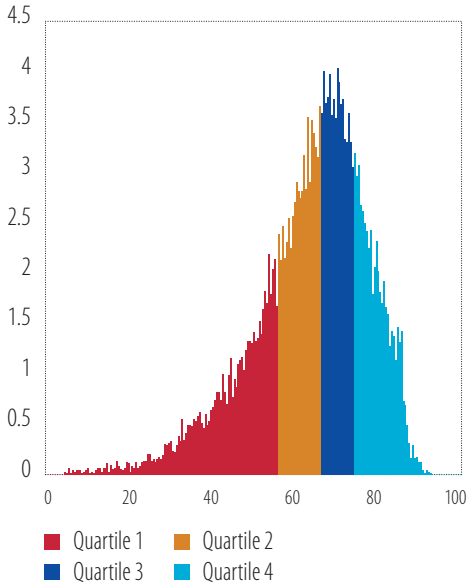
In sum, the technical factor energy efficiency evaluates how efficiently firms in the same sector use their resources, the technology gap ratio identifies technological advancements in that sector, and the meta integrates both measures, capturing the overall efficiency of a firm compared to the best possible performance across all sectors and technologies.

Energy efficiency gaps stemming from technological and governance challenges

The energy efficiency performance of European firms varies significantly from sector to sector, underscoring the need for targeted policies to reduce inefficiencies and promote more sustainable practices. Using the meta-stochastic frontier analysis methodology described in Box B, firms' energy efficiency performance was assessed based on their ability to minimise energy spending given their output and inputs. The estimated meta score – ranging from 0 (least efficient) to 100 (frontier performance) – measures how close firms are to their most efficient counterparts within their sector and throughout different sectors, thereby assessing their operational efficiency. Figure 11 shows the distribution of European firms' energy efficiency performance based on a measure of sector meta-stochastic frontier analysis, highlighted by quartile. There is a strong dispersion in operational efficiency among firms in the lowest efficiency quartiles. Figure 12 illustrates the average EU meta scores by sector, highlighting that leading sectors exhibit higher operational efficiency and narrower technological gaps. The analysis reveals clear sector differences across Europe. Sectors that have so far not been among the most energy intensive or polluting (such as IT and telecommunications and electronics) excel in energy efficiency, while more critical sectors for decarbonisation (such as transport, energy, chemicals and pharmaceuticals, and construction) perform below the EU average.

Figure 11

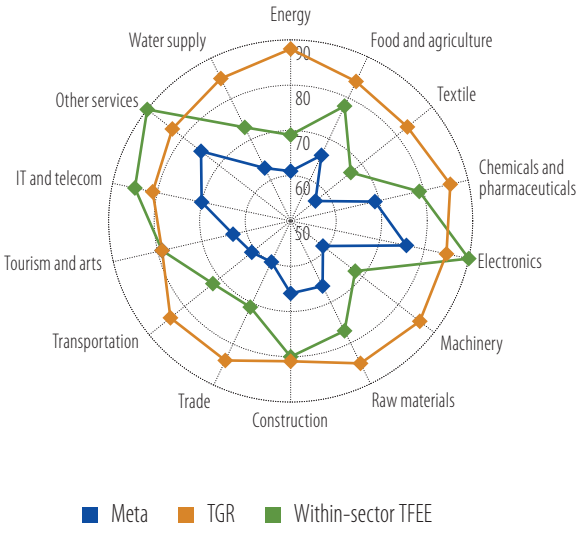
Density distribution of EU firms' energy efficiency performance (meta score)**, by quartile**



Source: *EIB staff calculations based on EIBIS 2023-2024.*
Note: *Density distribution of energy efficiency performance (meta scores) across performance quartiles. The quartiles have been calculated based on the overall EU data for 2023 and 2024. The indexes range from 0 to 100%, with 100% reflecting frontier firms.*

Figure 12

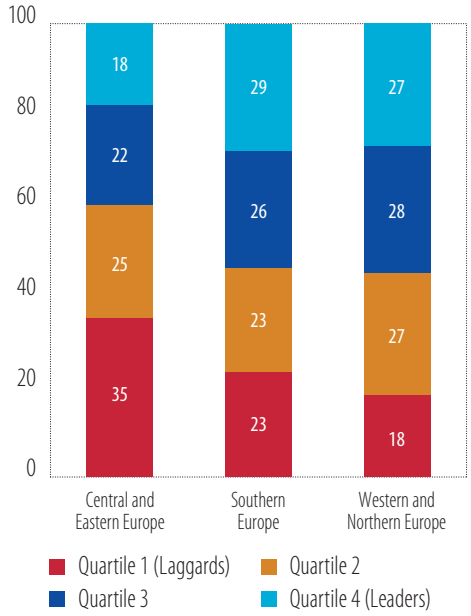
Average energy efficiency (meta)**, technology gap ratio and technical factor energy efficiency scores of EU firms, by sector**



Source: *EIB staff calculations based on EIBIS 2023-2024.*
Note: *The figure shows the average energy efficiency performance (across sector comparison), the technology gap ratio (TGR) and the technical factor energy efficiency (TFEE) of firms within a specific sector.*

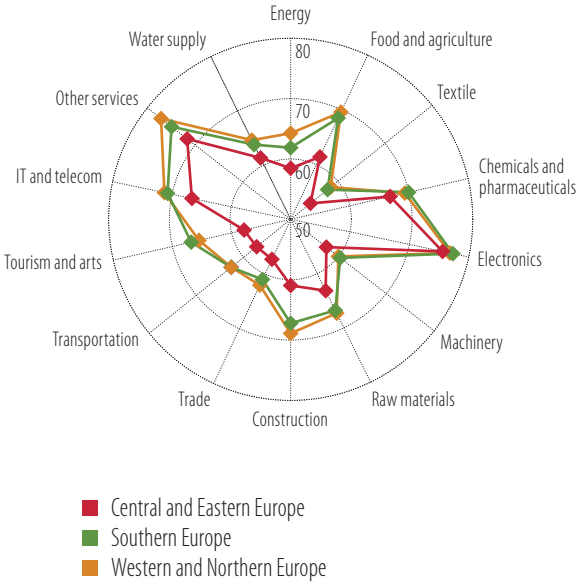
Regional disparities in energy efficiency performance are also evident. Figure 13 shows the distribution of meta scores in the different performance quartiles for different European regions, while Figure 14 provides average sector scores by region. According to both figures, firms in Western and Northern Europe consistently achieve the highest energy efficiency scores, reflecting the advanced technologies they use and more efficient operations. Southern Europe follows, while Central and Eastern European firms lag behind, highlighting opportunities for significant improvement. For example, the meta analysis suggests that textile firms in Central and Eastern Europe could reduce their energy expenditure to turnover ratio up to 50% to match similar firms' energy performance in Western and Northern Europe, with the same inputs and outputs and production technology.

Figure 13
Distribution of EU firms' energy efficiency performance (meta score)**, by quartile and region**



Source: *EIB staff calculations based on EIBIS 2023-2024.*
Note: *The quartiles have been calculated based on EU data for the last two years.*

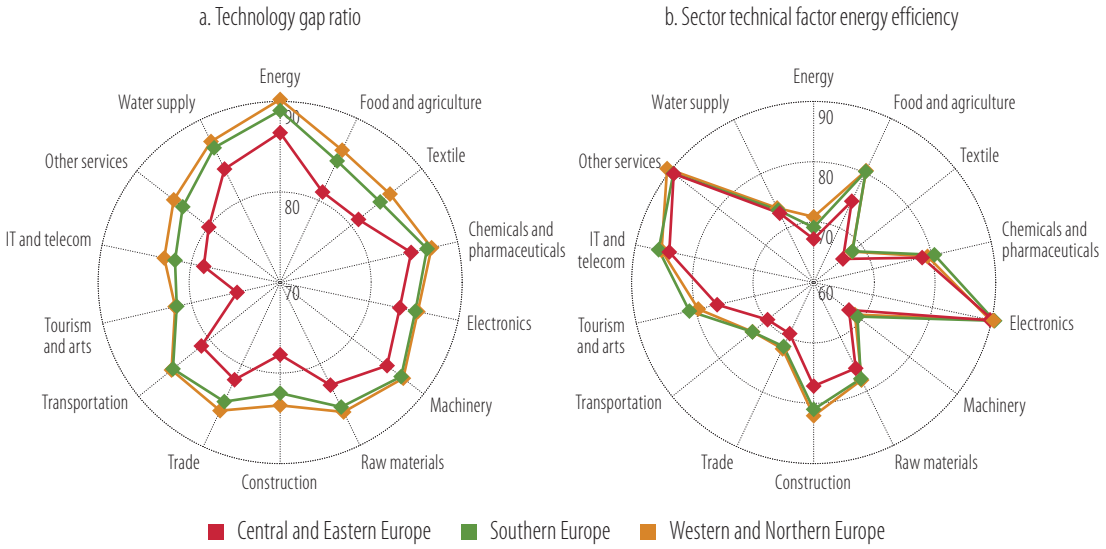
Figure 14
Average energy efficiency of EU firms, aggregated (meta scores)**, by sector and region**



Source: *EIB staff calculations based on EIBIS 2023-2024.*
Note: *See Box B for more information on the indicators. The index ranges from 0 to 100%, with 100% reflecting frontier firms.*

These disparities can be explained by differences in technology adoption (technology gap ratio) and operational energy management (technical factor energy efficiency within a specific sector). For instance, firms in sectors such as electronics, chemicals and pharmaceuticals, and IT and telecommunications perform well in all regions (Figure 15, right panel), with relatively small differences between firms in the same sector across the European Union. This indicates that in these sectors firms show high operational efficiency, given the available technology. However, despite the higher technical factor energy efficiency, these industries do not implement cutting-edge solutions (Figure 15, left panel), as reflected by their low technology gap ratios. Further efficiency gains will therefore come from adopting state-of-the-art technologies rather than merely improving current operational practices.

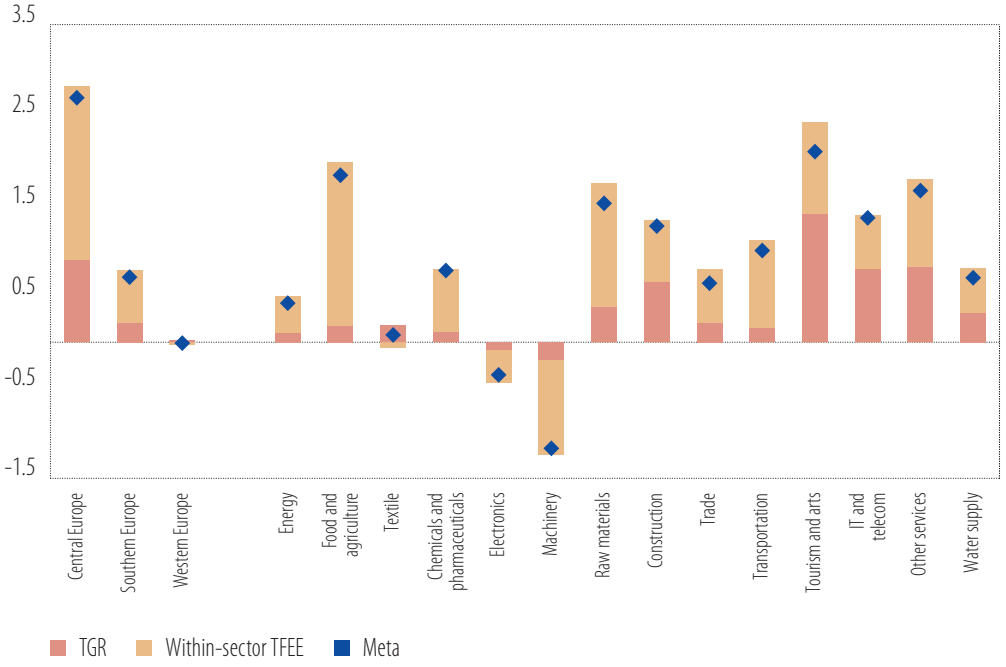
Figure 15
Average within-sector TFEE and TGR, by sector and region



Source: *EIB staff calculations based on EIBIS 2023-2024.*
Note: *The index ranges from 0 to 100%, with 100% reflecting frontier firms.*

Source: *EIB staff calculations based on EIBIS 2023-2024.*
Note: *The index ranges from 0 to 100%, with 100% reflecting frontier firms.*

Figure 16
Decomposition of meta scores (% change from the prior year)**, by sector and EU region 2023-2024**



Source: *EIB staff calculations based on EIBIS 2023-2024.*
Note: *The meta score change and technology gap ratio (TGR) and within-sector technical factor energy efficiency (TFEE) contributions are calculated as the percentage change for 2023 compared to 2022 for EU regions and sectors.*

In contrast, firms in sectors like textiles, machinery, trade and energy have much lower energy efficiency scores, suggesting that companies suffer from operational inefficiencies even where advanced technology is available. Despite access to better technology as indicated by their higher technology gap ratio ratios (Figure 15), firms in these sectors are not fully utilising energy-efficient practices. This inefficiency could be due to poor management, a lack of skilled labour or suboptimal use of the technologies available. For example, firms in the transportation sector in all regions could reduce their energy expenditure to turnover ratio by up to 30% by enhancing their operational efficiency while continuing to use current production technologies.

Energy efficiency performance improved in all sectors and regions from 2023 to 2024, with previously lagging sectors and regions making notable progress. As shown in Figure 16, while sectors such as machinery and electronics experienced marginal drops in meta scores due to operational inefficiencies, industries like food and agriculture saw the largest improvements, driven by enhanced operational efficiency and technological upgrades. Raw materials, construction and tourism also recorded substantial gains. Central Europe had the greatest regional improvement, with an average 3% increase in energy efficiency performance, primarily by way of improved operational practices and a narrowing technological gap. Western and Northern Europe continued to lead, maintaining stable efficiency levels and setting the performance frontier.

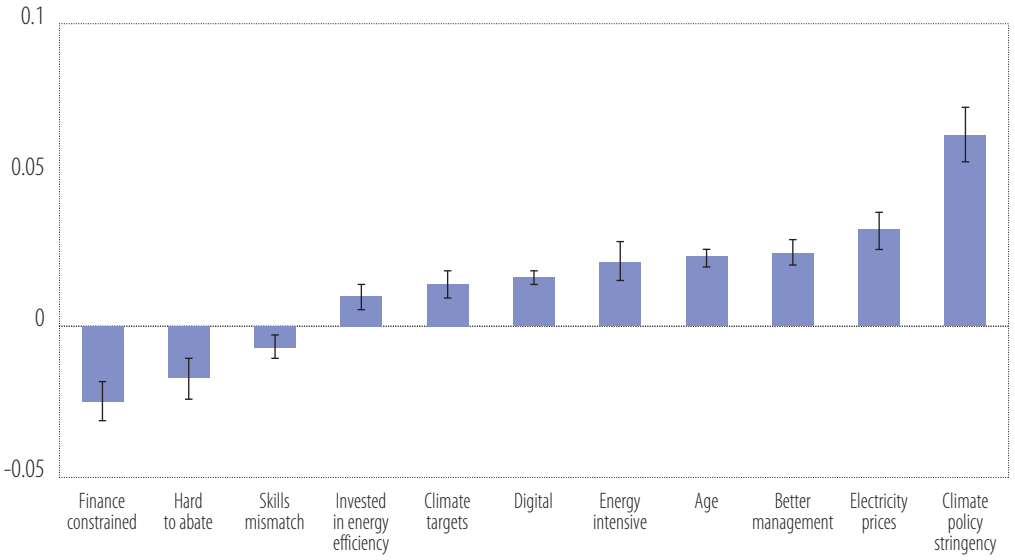
Firms' energy efficiency performance hinges on internal strategies and external factors

Firms' energy efficiency performance is shaped by internal and external factors. Internal factors include firm-specific elements such as financial constraints, management practices and the extent of their digital transformation. Meanwhile, external influences such as climate policy stringency and industry and country-related dynamics also play a crucial role. Figure 17 shows the estimated impact (marginal effects) of the determinants on firms' operational energy efficiency level, capturing the marginal effects of these factors using a standard ordinary least squares (OLS) regression. Conversely, Figure 18 takes a broader approach by using a multinomial logit model to illustrate how likely firms are to reach higher quartiles of energy efficiency. Together, these analyses offer a more comprehensive picture of the mechanisms driving energy efficiency and the factors that support firms in both gradual improvements and larger, more impactful changes.

The most significant factor enhancing firms' energy efficiency performance is the stringency of climate policy. Stricter regulations create the pressure needed to encourage firms to adopt energy-saving measures, as seen in sectors subject to the EU Emissions Trading System (Barrera-Santana et al., 2022). Firms in regions with stronger climate policies not only face higher compliance costs, but also benefit from a greater push to innovate and adopt cutting-edge energy-efficient technologies. This demonstrates that policy interventions are key in fostering widespread progress towards more sustainable and energy-efficient business practices across Europe.

Figure 17

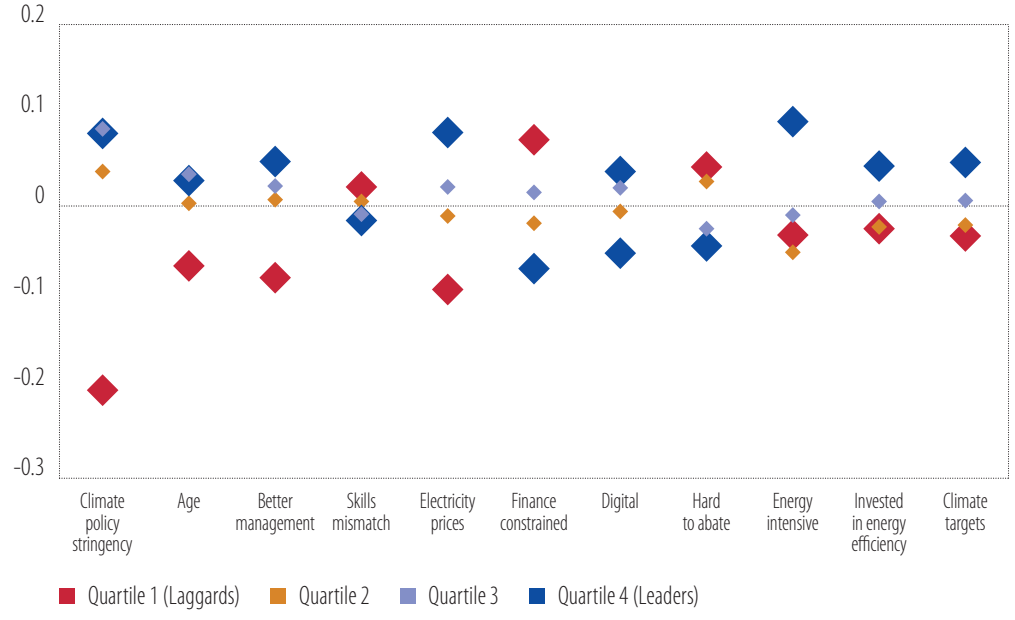
The impact of various determinants on energy efficiency performance (intensive margin)



Source: *EIB staff calculations based on EIBIS 2023-2024.*
Note: *The blue bars represent the intensive marginal effects of various factors on energy efficiency, as represented by the meta score, accounting for year and size effects. The black lines indicate 95% confidence intervals.*

Figure 18

Probability of firms belonging to different quartiles of energy efficiency performance (extensive margin)**, based on various determinants**



Source: *EIB staff calculations based on EIBIS 2023-2024.*
Note: *The first quartile represents firms that are lagging behind, and the fourth quartile those that are leading.*

Market conditions also play a crucial role in shaping firms' energy efficiency performance. High energy prices compel firms to reduce operational costs by adopting energy-saving technologies. This effect is particularly pronounced in energy-intensive sectors, where cost pressures force firms to prioritise investments in energy efficiency to maintain their competitiveness. However, firms with fewer

resources (especially those in the lower quartiles of energy performance) often struggle to capitalise on these opportunities, leaving them vulnerable to energy price fluctuations.

Firms with more advanced internal capabilities are better positioned to save energy. Better management practices, digital transformation and climate targets enable firms to improve their energy efficiency. Firms with better management practices consistently outperform their peers by implementing clear strategies, allocating resources effectively and fostering a culture of innovation (Niu et al., 2022). Digital transformation enhances energy efficiency by optimising operational processes, reducing downtime and facilitating the adoption of clean technologies. Firms that integrate digital tools into their energy management systems save significantly on energy costs, particularly in energy-intensive sectors such as chemicals and machinery (Lin and Huang, 2023). Setting climate targets provides firms with a clear roadmap, encouraging accountability and attracting green financing to support energy-efficient investments.

Despite these drivers, various barriers hinder firms' progress in improving energy efficiency. Financial constraints remain one of the most significant challenges, particularly for SMEs, which often lack access to affordable capital to pay for energy-efficient upgrades (Islam and Luo, 2016). Similarly, skill mismatches prevent firms from fully utilising advanced energy-efficient technologies, especially in industries such as raw materials, construction and agriculture. Addressing these barriers with targeted policy measures like training programmes and financial support mechanisms will encourage the broader adoption of energy efficiency in all sectors and regions.

Industry challenges also shape firms' energy efficiency performance. Energy-intensive firms are more likely to invest in energy-efficient technologies because of the substantial long-term cost savings these investments provide. However, firms in hard-to-abate sectors face inherent difficulties linked to the nature of their processes. While these firms often struggle to reduce their energy intensity, adopting advanced technologies and digital solutions can help them improve their energy efficiency. This underscores the importance of fostering innovation and supporting the development of new technologies to bridge the energy efficiency gap in these challenging sectors (Niu et al., 2022).

Energy efficiency measures can improve firms' financial performance

Energy efficiency gains lead to reduced operational costs and increased profitability in several key ways. First, improving energy efficiency directly lowers firms' energy bills, freeing up resources for other investments or expansions. Additionally, by optimising energy use, firms reduce waste and downtime, which enables them to produce more with fewer resources. Productivity gains also increase firms' competitiveness in the market and allow for greater investment in new technologies that further enhance energy efficiency. This positive feedback loop can help energy-efficient firms sustain long-term profitability.

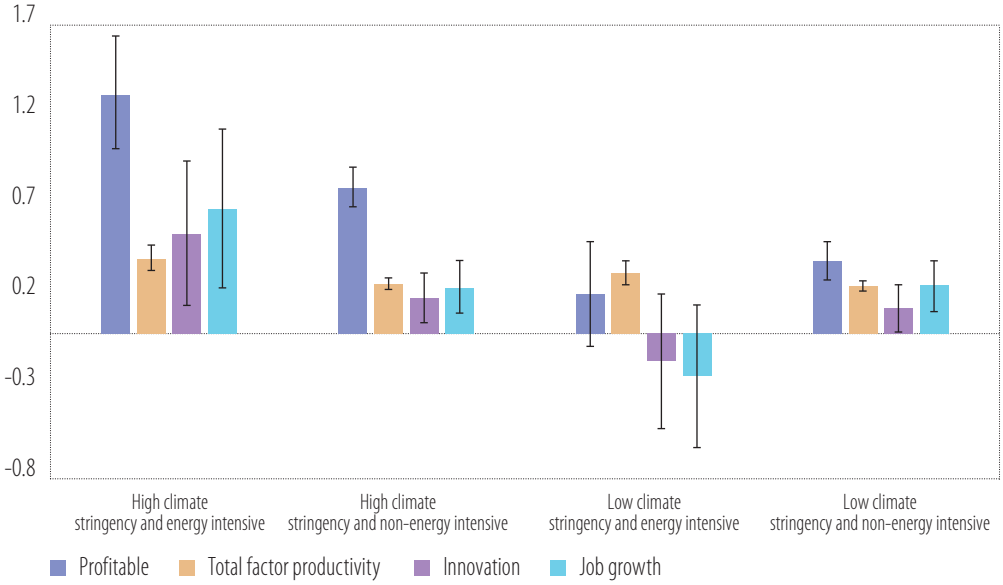
Stricter climate regulations have an impact on firm's performance, particularly for those in energy-intensive sectors. Figure 19 illustrates the estimated impact of energy efficiency on different performance indicators under varying climate policy stringency and energy intensity. Under stringent policies, firms that have improved their energy performance experience substantial gains in profitability, total factor productivity, innovation and job creation. The incentives to transform under these conditions are clear, with heightened regulatory pressure driving investments in energy-saving technologies, improved operations and innovative processes. Both firms in energy-intensive and non-energy-intensive industries benefit from improved energy efficiency with stricter regulation. Non-energy-intensive firms benefit to a lesser extent because their compliance costs are generally lower, but they still leverage energy efficiency to enhance performance.

With more lenient climate regulations, firms in energy-intensive industries have fewer incentives to improve their energy efficiency. Figure 19 shows that, in this scenario, the economic benefits are marginal and not statistically significant without strong regulatory drivers (Martin et al., 2014). The high costs and limited returns of transitioning to energy-efficient operations reduce the appeal of such investments, in line with the findings of existing literature (DeCanio, 1993; Allcott and Greenstone, 2012).

In the same way, a low stringency environment considerably reduces the benefits of being more efficient in non-energy-intensive sectors, especially the likelihood of being more profitable than less efficient firms. This highlights how differences in cost structures, climate regulation and energy dependencies shape firms' motivation to pursue energy-efficiency improvements.

Figure 19

Impact of energy efficiency (meta score) **on firms' performance, by climate policy stringency and energy intensity**



Source: *EIB staff calculations based on EIBIS 2023-2024.*
Note: *The bars represent the marginal effects of energy efficiency on the probability of being profitable, productive, innovative, and increasing firm's employment, after accounting for year, and size effects. Climate policy stringency uses a normalised sub-indicator from the Climate Change Performance Index that assesses the strictness of national and international climate policies. The black lines indicate 95% confidence intervals.*

Box C

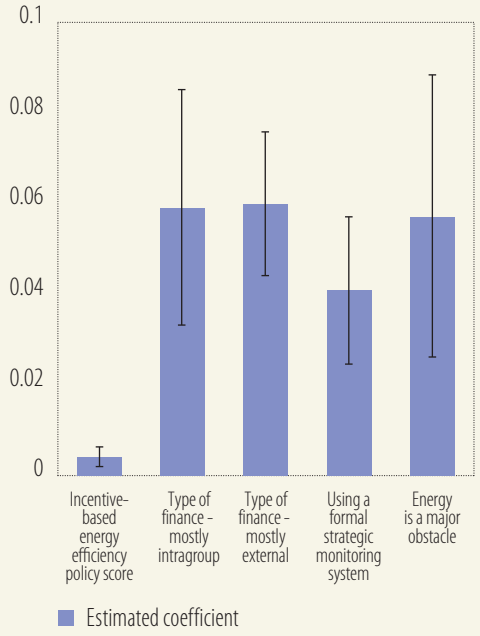
Firms' energy efficiency investment depends on the regulatory environment and access to finance

Firms' energy efficiency investments have the potential to lower energy costs and raise competitiveness. On the other hand, energy efficiency accounts for a sizeable share of firms' investment, and high financing costs and suboptimal regulatory environments may pose significant challenges to its deployment. More than two in five EU firms invested in energy efficiency from 2018 to 2022, directing an average of 23% of their total investment to this area. Three-quarters of firms investing in energy efficiency during this time spent more than EUR 11 715, and half of them spent an average of more than EUR 61 650.

The proportion of EU small and medium businesses investing in energy efficiency differs depending on the source of their finance. One-third of firms that rely mainly on internal finance have invested in energy efficiency vs. 44% of firms that rely mainly on external finance. In addition, SMEs relying mainly on internal funding direct a smaller share of their total investment to energy efficiency than their peers relying mainly on external finance (24% vs. 30%, respectively). This analysis shows that in some cases, firms' energy efficiency investment is constrained by financial frictions, with improved access to external sources of finance potentially enabling businesses (particularly SMEs) to make these long-term investments.

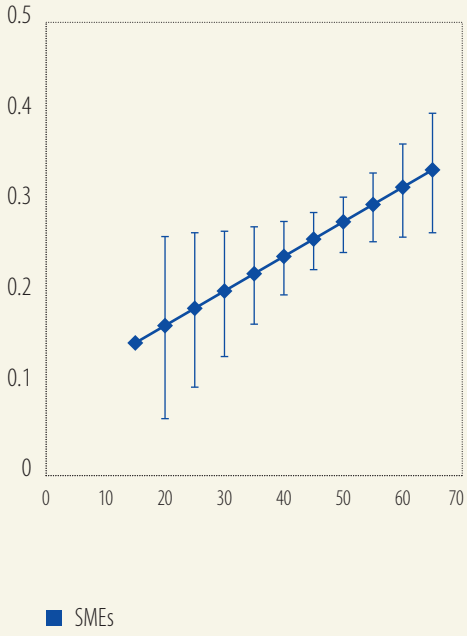
There are also other economic and regulatory factors beyond finance that predict how likely firms are to invest in energy efficiency and the intensity of this investment. Econometric estimations suggest that the decision to invest in energy efficiency is associated with economic factors such as size, profitability, perceiving energy costs as a barrier to investment, and the use of a formal strategic monitoring system or advanced digital technologies.[3] In addition, operating in a country with a favourable energy efficiency regulatory environment has a positive and statistically significant relationship with a firm's decision to make energy efficiency investments.[4] One way to measure the strength of the regulatory environment is to look at the strength of its incentive-based component. This is reflected in the proportion of incentive-based policies (policy measures designed to encourage and orient energy efficiency investment) captured within the overall Regulatory Indicators for Sustainable Energy (RISE) energy efficiency scores.

Figure C.1
Drivers of energy efficiency



Source: *EIB staff calculations based on EIBIS 2018-2022.*
Note: *The results are estimated from a second stage Heckman selection model. The calculations use an inverse mills ratio from the first stage probit model to correct for selection bias. The estimates include entity and time fixed effects for 2018-2022. They also control for firm size, age, profit, total fixed assets and level of digitalisation.*

Figure C.2
The impact of adopting effective regulation on firms' investment in energy efficiency (a coefficient)



Source: *EIB staff calculations based on EIBIS 2018-2022.*
Note: *Post-estimation results of second stage Heckman selection model.*

A firm's decision to make energy efficiency investments is dependent on business size, access to external finance (particularly for SMEs), and whether it is operating in a country with a favourable regulatory environment. Once firms opt to make an energy efficiency investment, the intensity of this investment is predicted by their capacity to access finance, internal management practices and

3 See Tueske and Lasheras Sancho (forthcoming).

4 The World Bank Group's Regulatory Indicators for Sustainable Energy (RISE) evaluate the policy and regulatory landscape for energy efficiency in 140 countries, including 20 of the 27 EU Member States. The RISE energy efficiency score offers a comprehensive measure that makes it possible to examine the relationship between a country's policy environment and how likely firms are to invest in energy efficiency.

the strength of incentives in the regulatory environment. Estimation results suggest that once firms decide to invest in energy efficiency, their reliance on finance from internal or external sources and the score of national incentive-based energy efficiency regulatory policies are important factors encouraging firms to devote a larger share of their investment to energy efficiency. The use of a formal strategic business monitoring system and a perception of energy costs as a major obstacle to investment are also significant predictors of energy efficiency investment (Figure C.1).

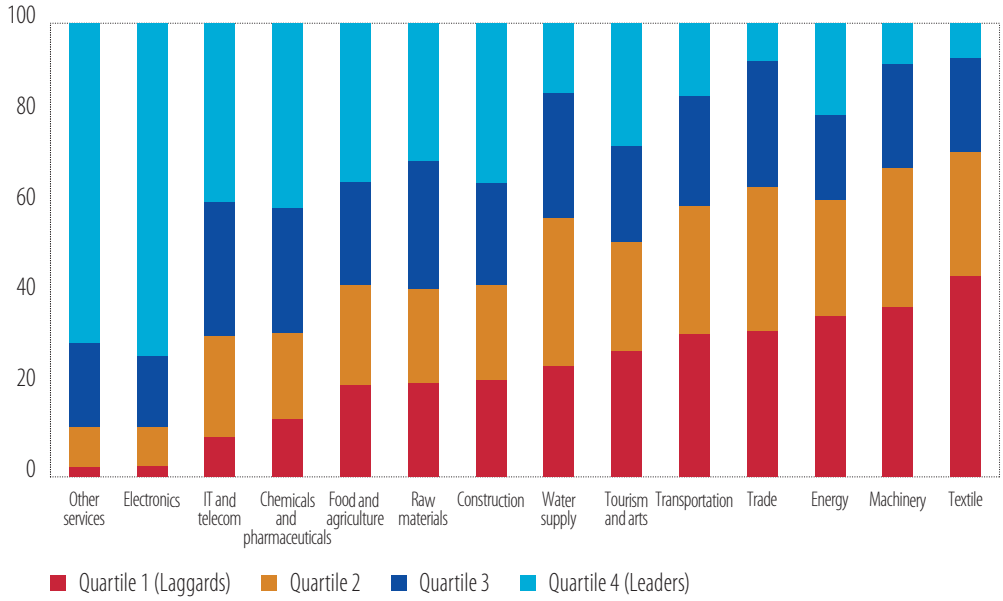
The estimation results can be used to simulate the impact of implementing best practices in energy efficiency regulation. How much SMEs invest in energy efficiency rises in line with the country's incentive-based regulatory score (Figure C.2). Closing the gap between the lowest and the highest energy efficiency regulatory policy score (25 points) could lead to a 9.5 percentage point increase in the share of total investment devoted to energy efficiency measures by SMEs in the least favourable environment. Enhanced access to finance for SMEs has the potential to further increase how much of their investment they direct to energy efficiency.

Energy efficiency leaders outperform laggards in economic performance and innovation

Energy efficiency laggards exist in almost all sectors – even those with good average performance. The gaps shown in Figure 20 highlight the untapped potential of energy efficiency improvements to deliver benefits for the environment, firms and the broader economy. Enhancing energy efficiency reduces costs, boosts competitiveness and supports sustainable growth, much like improvements in other production factors. However, firms often underestimate these benefits, focusing on short-term costs and returns. This tendency is further compounded by market failures such as information asymmetry, limited access to financing and misaligned incentives, making energy efficiency investments appear less appealing. By examining the economic performance differences between leaders (fourth quartile) and laggards (first quartile) under varying conditions, the subsequent analysis demonstrates how targeted improvements can address these disparities, unlock economic gains and align business objectives with environmental goals, creating a win-win outcome for all groups.

Figure 20

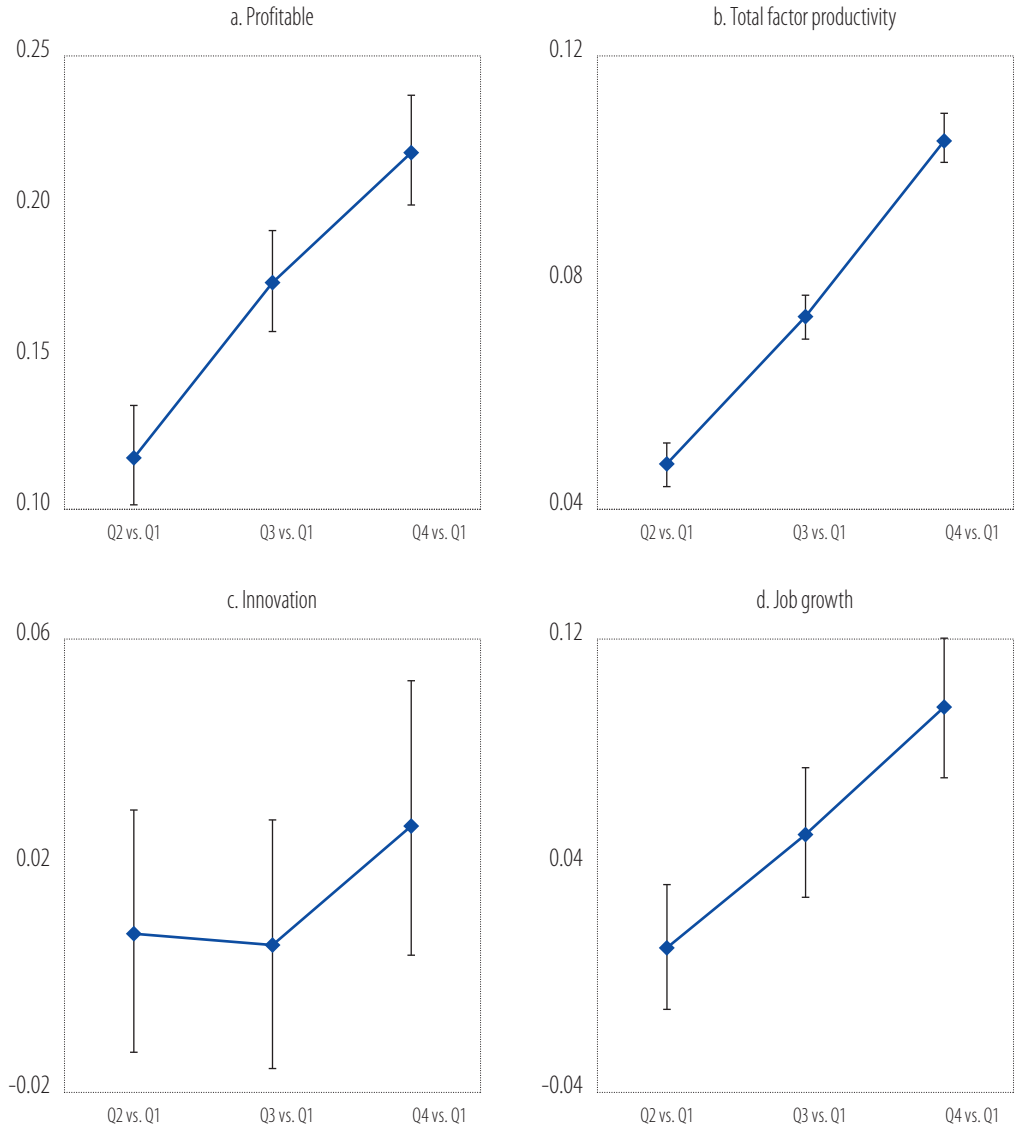
Distribution of EU firms' energy performance (meta score)**, by quartile and sector**



Source: *EIB staff calculations based on EIBIS 2023-2024.*
Note: *The bars represent the share of firms in each quartile based on their energy efficiency performance (meta score).*

Figure 21

Comparison of firms' performance across energy efficiency quartiles (meta score)**, comparison with the quartile 1 baseline**



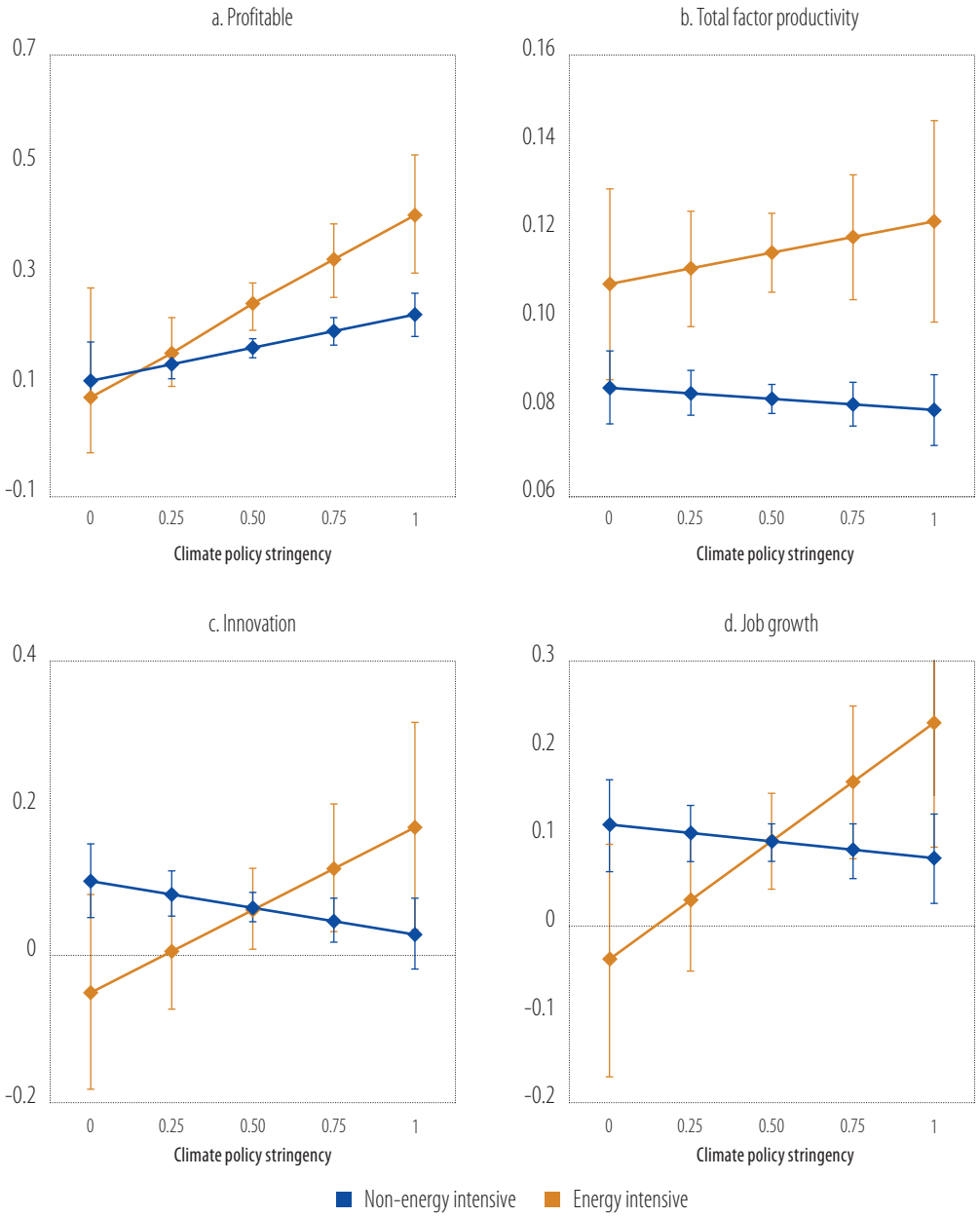
Source: *EIB staff calculations based on EIBIS 2023-2024.*
Note: *The blue dots represent the marginal effects of being in different energy efficiency quartiles on the probability of being profitable, productive, innovative, and adding jobs, after accounting for country, sector, year and size effects. Quartile 1 (laggards) is the baseline. The black lines indicate 95% confidence intervals.*

Improving energy efficiency enhances several measures of firm performance, including profitability, productivity, innovation and employment growth. Figure 21 shows the differences in outcomes for firms in the most efficient vs. least efficient quartile. Firms in the most efficient quartiles of energy efficiency exhibit stronger financial outcomes. The cost savings from reduced energy use translate into increased profitability, consistent with the conclusions of Barrera-Santana et al. (2022). Moreover, total factor productivity improvements are particularly pronounced, as energy-efficient firms optimise resources, leading to higher output, which mirrors findings from Honma and Hu (2018). Although the effect on innovation is less pronounced, the likelihood of adopting advanced technologies and innovative processes rises with energy efficiency, supporting research by Palm and Thollander (2010) indicating that energy-efficient firms foster a culture of continuous improvement. Additionally, firms with

higher energy efficiency tend to experience greater job growth, aligning with the broader economic benefits of energy-efficient practices. This suggests that energy efficiency not only sharpens firms ability to compete, but also contributes to the broader economy through innovation and job creation.

Figure 22

Comparison of firms' performance between energy efficiency leaders (quartile 4) **and laggards** (quartile 1) **in energy-intensive vs. non-energy-intensive sectors as climate regulations become more stringent**



Source: *EIB staff calculations based on EIBIS 2023-2024.*

Note: *The lines represent the marginal effects of energy efficiency on the probability of being profitable, productive, innovative, and adding jobs, under different climate policy stringency levels in energy-intensive and non-energy-intensive sectors, after accounting for year and size effects. Climate policy stringency refers to a normalized sub-indicator from the Climate Change Performance Index, which assesses the strictness of national and international climate policies. The vertical lines indicate 95% confidence intervals. Energy efficiency performance measured by meta score.*

Higher energy efficiency improves profitability, especially for companies that must adhere to stricter climate policies. While stricter climate policies can negatively impact profitability, they also provide a competitive advantage to energy-efficient firms (Figure 22). Companies that improve their energy efficiency – particularly when they move from lower to higher efficiency quartiles of the distribution – significantly increase their likelihood of being profitable. The shift is more pronounced in countries with stricter climate policies, as firms in these areas face higher compliance costs and have an incentive to optimise their energy use to maintain or enhance their margins. This aligns with the findings of Dechezleprêtre and Glachant (2014), who show that firms adopting energy-efficient technologies benefit from reduced operational costs, especially when faced with stringent regulatory environments. In conclusion, improving energy efficiency helps to reduce costs and gives firms in regions with demanding climate policies a competitive edge.

Stricter climate policy amplifies energy efficiency gains, particularly in energy-intensive sectors. The greatest benefits go to firms that are more energy efficient (when comparing leading firms to laggards), operate under strict climate regulations and are energy intensive. This trend reflects the broader literature on environmental regulation and firm behaviour, which posits that stringent policies can spur improvements in efficiency by internalising the cost of carbon and encouraging investment in energy-saving technologies (Porter and van der Linde, 1995). Energy-intensive firms, which are more exposed to carbon pricing mechanisms like the EU Emissions Trading System, tend to benefit more from these efficiency improvements (particularly for profitability and total factor productivity), as shown in Figure 22. This confirms findings from Costantini et al. (2017) showing that firms facing stricter regulations often perform better environmentally and economically because they are more innovative and use resources more efficiently.

Box D

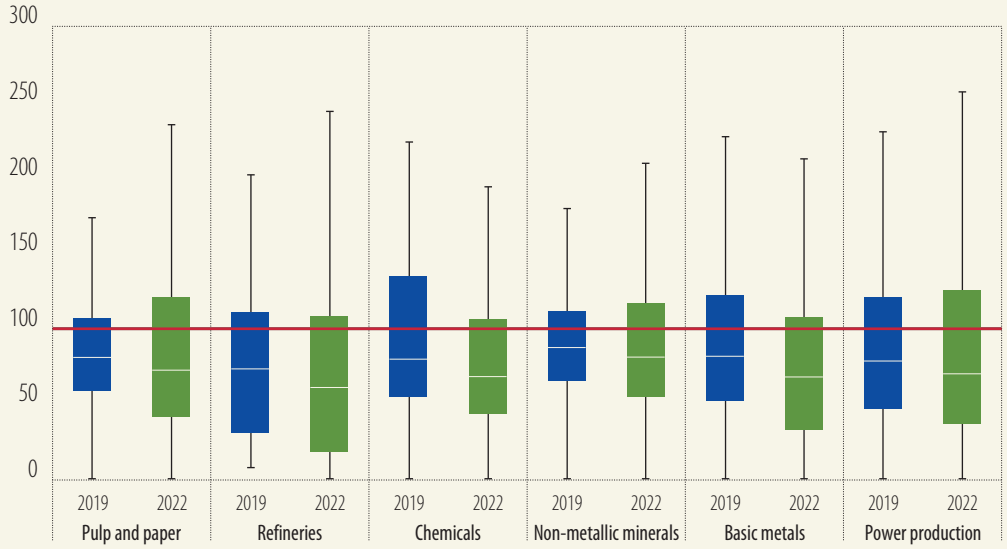
Decarbonisation in sectors covered by the Emissions Trading System depends on leaders' actions and laggards' adaptation

The EU Emissions Trading System (ETS) is one of the world's most ambitious market-based climate initiatives, and it is a keystone of the European Union's drive to reach net-zero emissions by 2050. Founded in 2005 and now covering around 15 000 installations (factories or plants) in climate-critical sectors like energy, manufacturing, aviation and maritime transport, the system covers nearly 40% of Europe's emissions. It applies a gradually tightening emissions cap to reduce the supply of free emissions allowances over time, thereby encouraging companies to cut emissions in a cost-effective manner. While progress has been substantial, there is a marked divide in the decarbonisation of different sectors and even within individual industries, with some firms leading in carbon efficiency while others lag behind.

The power-generation sector is a leading example of how carbon pricing can drive emissions reductions. Emissions from power installations have dropped by over 50% since 2013, largely thanks to the deployment of renewable energy sources and a shift away from coal. This substantial decline is evidence of the system's ability to reshape industry behaviour by providing price signals for carbon, pushing firms towards cleaner operations than are less reliant on volatile fossil fuels. While slower to adapt, the manufacturing sector has also shown significant improvements, particularly as the Emissions Trading System entered Phase IV in 2021. Here, many manufacturers reacted to the reduction of free allowances and increased carbon prices by adopting greener technologies.

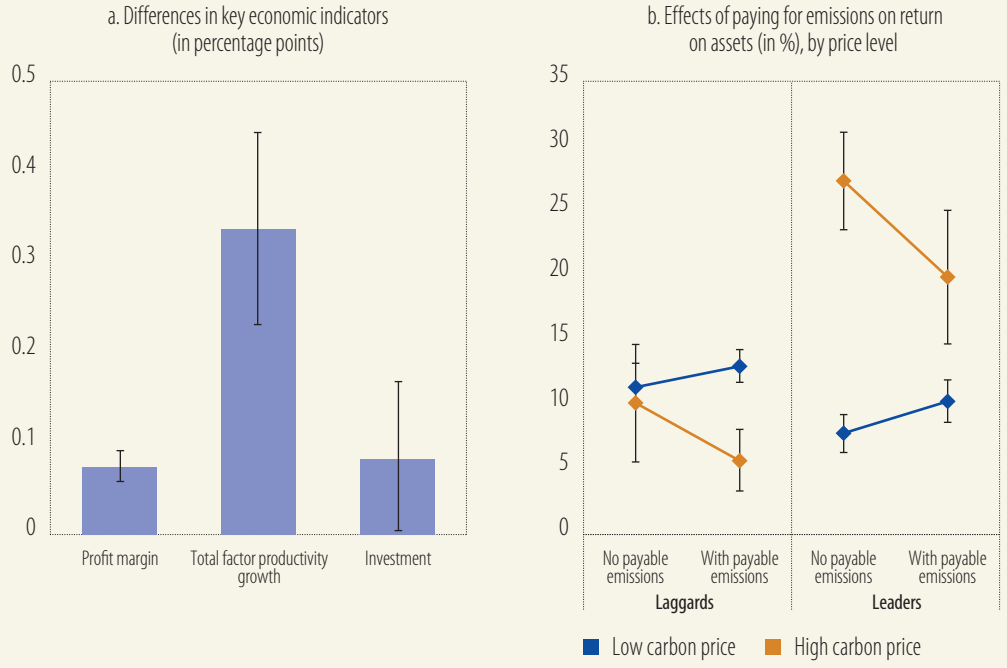
Nevertheless, despite overall progress, many firms are still struggling to decarbonise. While more than 50% of firms reduced their dependency on carbon-based fuels in each of the industries covered from 2019 to 2022, every sector has a share of firms that are falling behind (Figure D.1). In fact, more than 25% firms in pulp and paper sector and non-metallic minerals sector seems to have increased their dependency on carbon-emitting processes since 2022 compared to 2019. Furthermore, more than one-quarter of firms in each of the sectors had higher carbon dependency in 2022 than in 2013. This suggests that many firms are limited by the availability of carbon-free solutions for their core processes, highlighting the need for innovation and sector-specific support to close the gap between high performers and those facing more complex decarbonisation challenges.

Figure D.1
Distribution of the progress on decarbonisation (2013=100)**, by sector 2019 vs. 2022**



Source: *EU Emissions Trading System (ETS) and Bureau Van Dijk's Orbis database.*
Note: *Leaders are those in the 25th percentile of firms with the biggest drop in carbon intensity from 2013, while laggards are firms in the 75th percentile.*

Figure D.2
Differences in economic performance, leaders vs. laggards



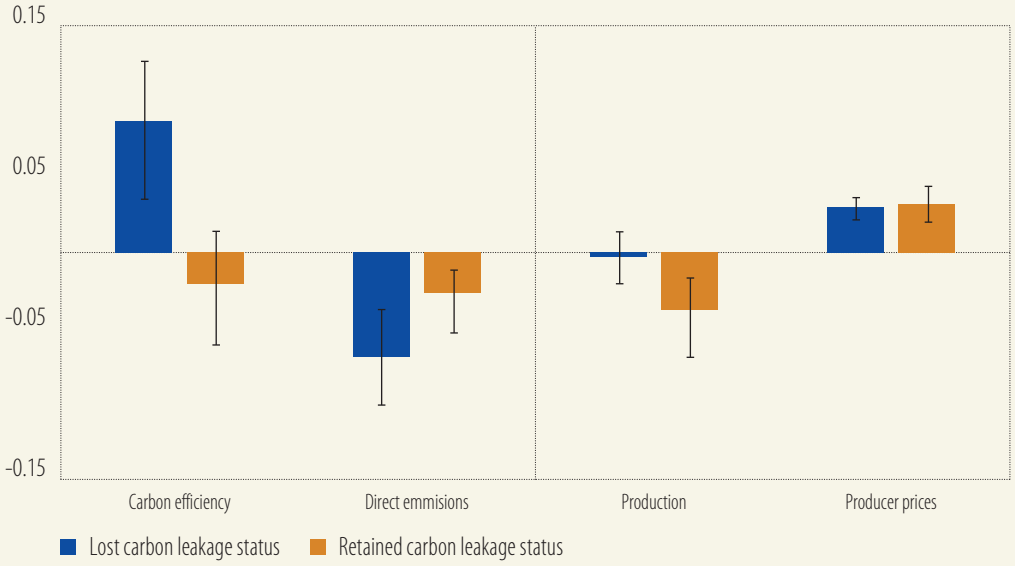
Source: *EU ETS and Orbis.*
Note: *Panel a plots the average difference in variables between leaders and laggards, controlling for sectoral fixed effects. Panel b plots the marginal effects of a one euro increase in ETS prices on the return on assets, controlling for the firm-level fixed effects, the level of total assets, the sales-to-asset ratio and cash-to-asset ratio. Payable emissions are calculated as a difference between actual emissions and free allocations. The calculations refer to the EU manufacturing sector.*

The divide between leading and laggard firms covered by the Emissions Trading System underscores the role of green technologies and the need to invest in them. Leading firms have consistently pursued cleaner production methods and energy-efficient systems, as reflected by higher investment ratios, positioning themselves at the forefront of emissions reduction. This commitment has not only decreased their carbon intensity, but also enhanced productivity (Figure D.2a). For instance, post-pandemic data show that leading firms, with stronger investment in capital assets, showed noticeable growth in total factor productivity, a measure of efficiency gains that signals modernisation efforts.

These leaders illustrate how proactive investment in decarbonisation technologies – whether in production equipment or operational processes – can yield dual benefits. By investing early and strategically, these firms improve their environmental footprint and their competitiveness. The shift to mandatory allowance purchases in Phase IV of the trading system[5] has only accelerated this trend (Figure D.3), as companies that previously received free allowances now have an incentive to reduce emissions to avoid rising costs (Hagerdon et al., 2024). The expansion of the trading system will spur more industries to transform, underscoring the system's ability to foster climate action and improved economic resilience (Kalantzis et al., 2024).

Figure D.3

Impact of ETS prices on the carbon and economic performance of sectors (a coefficient for marginal effects)**, based on carbon leakage status**



Source: *EIB staff calculations based on EIBIS 2023-2024.*
Note: *For the model specification, see Hagerdon et al. 2024. The figure below shows the changes in the allocation of free allowances for different sectors under the EU Emissions Trading System from Phase III (2013-2020) to Phase IV (2021-2030). The free allowances are granted to sectors that are exposed to a significant risk of carbon leakage, which means that they may relocate their production to countries with less stringent climate policies.*

While leaders forge ahead, a group of firms continue to fall behind in carbon efficiency. These laggards often face issues such as outdated technology and limited access to green production methods, and they struggle to meet ETS requirements at the same pace as their peers. Firms

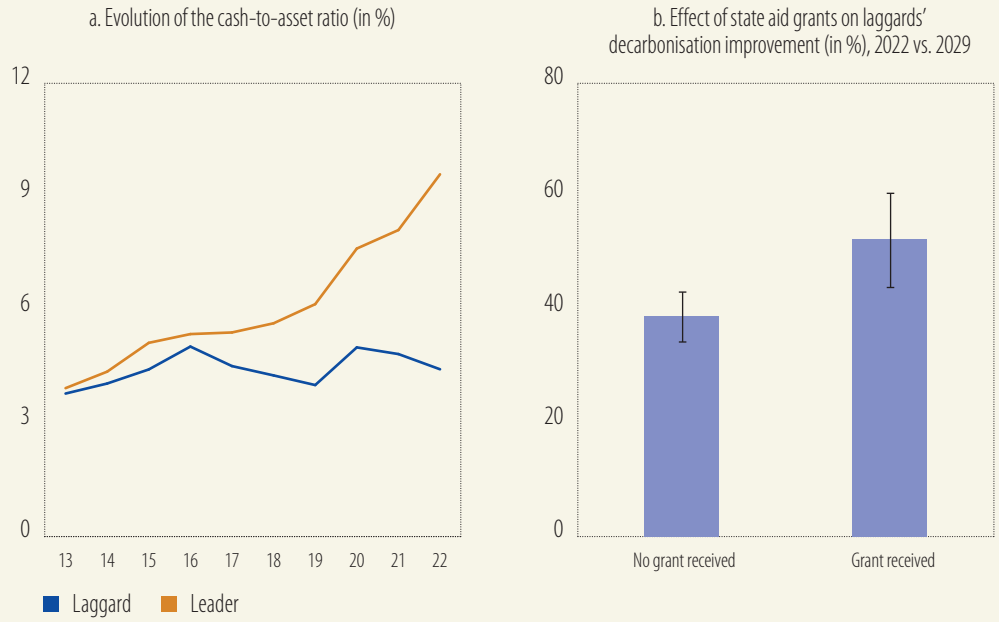
5 The EU Emissions Trading System (EU ETS) has evolved through four main phases since 2005. Phase 1 (2005-2007) was a pilot phase with free allowances, leading to overallocation issues. Phase 2 (2008-2012) aligned with the Kyoto Protocol, introduced some auctions and expanded coverage. Phase 3 (2013-2020) brought structural reforms like a single EU-wide cap and the Market Stability Reserve. Phase 4 (2021-2030) aims to reduce emissions 62% by 2030, with tighter caps and increased auctioning to align with the EU's climate goals. Each phase has progressively tightened the system to better achieve emissions reductions.

in sectors where carbon-intensive processes are integral (such as petrochemicals and lime production) often lack alternatives that would make significant emissions reductions feasible. This decarbonisation drag is not without consequences: as carbon prices rise, laggards find it harder to remain profitable. Unlike leaders, who have managed to offset carbon costs through efficiency gains or by passing them on through higher prices, laggards' profit margins are squeezed by high carbon costs (Figure D.2b). While on balance every incremental rise in the carbon prices cut into profits, laggards manage to keep moderate but stable cash reserves (Figure D.4a). Without major changes in operations or technology, these firms face the risk of becoming "brown zombies" – businesses unable to thrive in a greener economy, yet buoyed by considerable cash buffers and moderate state aid helping them to stay afloat.

Strategic policy support has proven essential to addressing these disparities. Some laggards have received state aid that has helped drive modest improvements in their carbon performance (Figure D.4b), especially during the challenging years of 2017 to 2019. For businesses with credible decarbonisation paths, such targeted financial aid can provide the funds and support they need to transition to more sustainable practices. However, policy needs to be applied with precision – untargeted aid risks subsidising firms that may lack the commitment or capability to green their business. While the share of emissions covered by free allowances has been steadily falling for industries with lagging firms, some 20% of those firms still received enough free allowances to completely cover their emissions in 2022, weakening the effectiveness of more stringent climate regulations.

Figure D.4

Cash buffers and the effect of state aid on carbon laggards and leaders



Source: *EU ETS, Orbis and the European Commission's state aid database.*
Note: *For panel b, the grant component is calculated as a sum of all grant-related support declared as state aid from 2017 to 2019. The calculations refer to the EU manufacturing sector.*

To sum up, the importance of fostering investment in carbon-reducing technologies cannot be overstated. Green investments act as catalysts, enabling companies to not only meet immediate ETS requirements, but also to position themselves competitively in a low carbon future. Many laggards will require a combination of tailored incentives, access to green financing and continued support for innovation if they are to overcome structural and technological barriers.

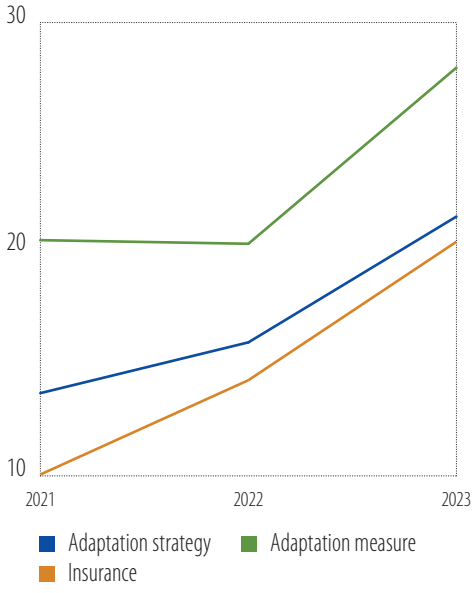
Adaptation is still overlooked in climate action

This section examines how firms and municipalities are responding to the growing need for climate adaptation. It highlights disparities in the characteristics of firms and municipalities, identifying barriers such as financial constraints, technical gaps and unclear regulations. Drawing on the EIBIS and the EIB Municipalities Survey 2024, it explores these challenges and connects them to concrete policies for building a more climate-resilient future.

Firms are making little progress on adapting to climate change, despite high awareness

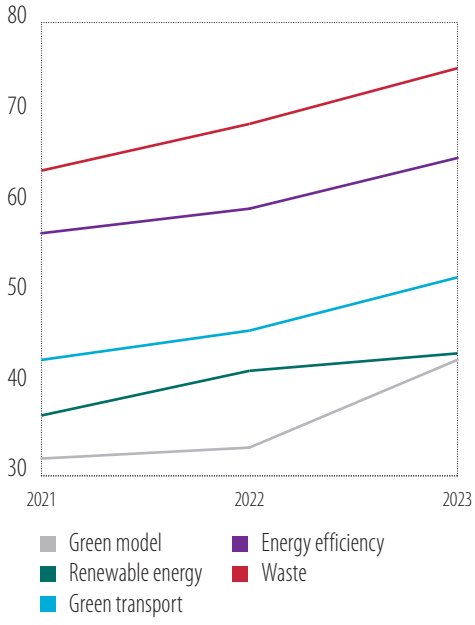
As the climate crisis intensifies, firms are increasingly aware of the need to address both mitigation (reducing greenhouse gas emissions) and adaptation (preparing for climate effects like extreme weather). However, data from the EIBIS reveal a clear imbalance: while a larger share of firms focus on mitigation, fewer are preparing for immediate climate risks. Figures 23 and 24 illustrate this disparity, showing that emissions-reduction measures are more widely adopted than preparations for climate-related disruptions. This imbalance exposes many firms to significant vulnerabilities from the intensifying physical impact of climate change. The analysis below explores critical trends, barriers and enablers shaping firms' adaptation efforts and emphasises the need for a more integrated approach that will help build Europe's resilience.

Figure 23
Investment in adaptation measures
(% of firms)



Source: *EIB staff calculations based on EIBIS 2022-2024.*
Question: *Has your company developed or invested in any of the following measures to build resilience to the physical risks to your company caused by climate change?*

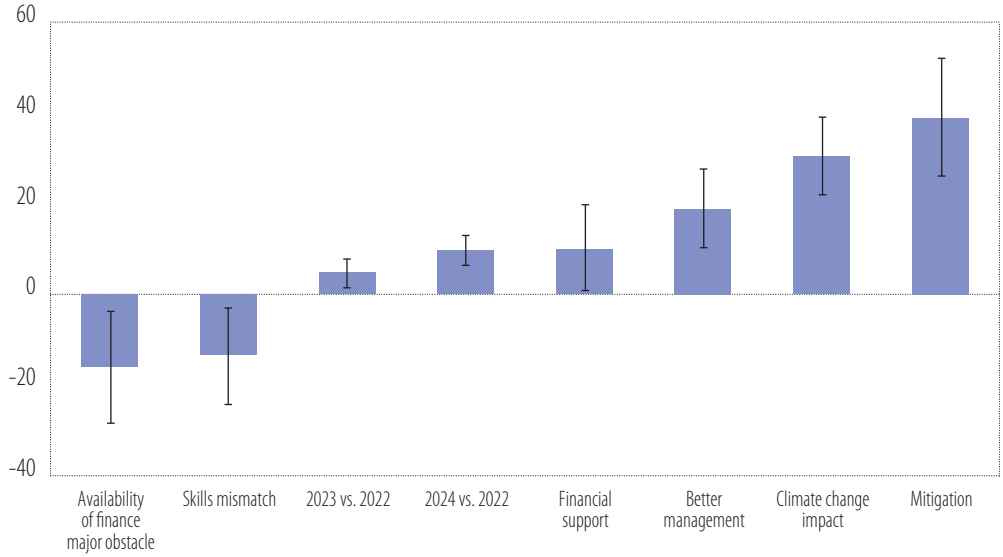
Figure 24
Investment in mitigation measures
(% of firms)



Source: *EIB staff calculations based on EIBIS 2022-2024.*
Question: *Has your company invested in or implemented the following, to reduce greenhouse gas (GHG) emissions?*

Encouragingly, firms' shifting perceptions reflect a growing but moderate commitment to adaptation. Evidence from the EIBIS 2023 and 2024 shows an increase in the willingness of firms to invest in adaptation compared to 2022 (Figure 25). This upward trend signals a growing recognition of the systemic risks posed by climate change and the role of preparedness in ensuring long-term business continuity. While the adaptation investments of different regions and firms are still uneven, estimated coefficients suggest that adaptation is increasingly seen as a vital component of climate resilience. This positive shift reflects an evolving corporate understanding of the need to protect operations against immediate and long-term risks.

Figure 25
Factors affecting the probability of investing in adaptation (in percentage points)



Source: *EIB staff calculations based on EIBIS 2020-2024.*
Note: *The marginal effects of investing in adaptation, taking into account the availability of finance as a major obstacle, employee skills mismatch, the change compared to 2022, receiving financial support, having better management practices, having been affected by extreme weather events and having invested in mitigation. The results are based on a panel logit regression that takes into account the estimated weighted average of the above factors by country, year and sector, after excluding the data points that equal either 0 or 1.*

Firms tend to prioritise adaptation investments in response to direct, tangible climate risks, such as extreme weather. The econometric analysis reveals a strong association between prior exposure to physical risks and adaptation efforts, in line with existing literature that suggests adaptation is often reactive in nature (Berkhout et al., 2006). However, this reactive approach creates vulnerabilities for firms in less-affected regions or sectors, where the absence of damaging events may delay them from becoming proactive. The findings underscore the importance of encouraging pre-emptive adaptation strategies to mitigate future risks.

Despite increasing awareness, adaptation remains constrained by financial and skill-related barriers. Effective adaptation requires expertise in areas such as assessing climate risks and planning for worst-case scenarios, and this is not always readily available. Unlike mitigation, which often relies on standardised technological solutions, adaptation requires tailored, context-specific interventions. Without access to the necessary human capital, many firms struggle to design and implement effective adaptation strategies (Hallegatte et al., 2011).

Financial constraints also pose a challenge. Firms that engage in adaptation are more likely to report being finance-constrained, reflecting the significant upfront costs associated with measures such as infrastructure upgrades or climate-risk modelling. This finding is consistent with studies highlighting the financial burden of adaptation on smaller firms or those with limited resources. To this end, financial

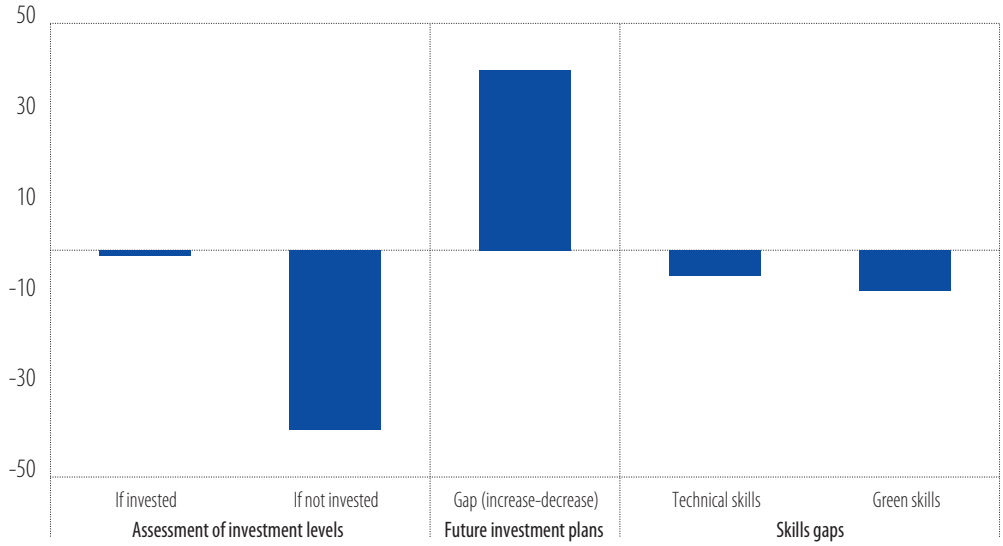
support can play a role in overcoming financial barriers to adaptation. The econometric analysis demonstrates a significant positive relationship between access to finance with favourable conditions and grants, and how likely firms are to adopt adaptation measures.

Finally, adaptation and mitigation are mutually supportive strategies for resilience. The findings highlight how adaptation and mitigation can work in tandem to foster true resilience. Adaptation addresses immediate vulnerabilities, while mitigation tackles the underlying drivers of climate risks by reducing greenhouse gas emissions. Together, these strategies equip firms to ensure short-term operational continuity and long-term sustainability. By combining adaptation measures (such as flood-resilient infrastructure) with mitigation actions (such as energy efficiency improvements), firms can create synergies that enhance their overall resilience to climate challenges.

Resource constraints hinder municipalities' ability to adapt to climate change

Municipalities across the European Union are also grappling with the pressing challenge of climate adaptation. They are striving to mitigate risks while addressing persistent gaps in green infrastructure investment. Insights from the EIB Municipalities Survey 2024 show that adaptation projects face unique obstacles – ranging from funding shortages to systemic coordination issues – that hinder progress, even as a growing number of municipalities (63%) recognise climate change as a significant challenge (EIB, forthcoming).

Figure 26
Local investment and skills mismatch (in %)

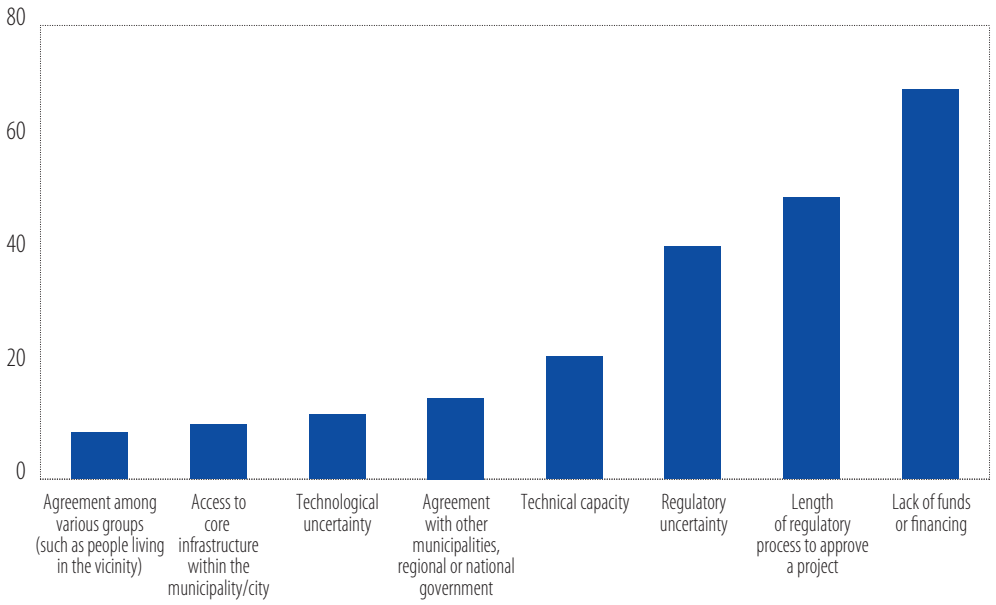


Source: *EIB Municipalities Survey 2024, EIB staff calculations.*
Note: *The gap in the level of investment is calculated as a difference of answers to Part a of the survey question: broadly adequate – sum of lacking (slight lacking and substantially lacking). The gap in future investment is calculated as a difference of answers to Part b of the survey question: increase and decrease in future average annual investment in the two areas compared to the previous three years. The skills gap refers to Part c of the survey question. Technical skills refer to engineering (technical) skills, while green skills refer to environmental and climate assessment skills.*
Question: *(a) In the last three years, that is, between the start of 2021 and the end of 2023, would you say that within your "municipality"/"city" the level of investment in infrastructure projects was broadly adequate, slightly lacking or substantially lacking in each of the following areas? (b) For each of the following areas, if you compare the average annual infrastructure investment you are planning for the 2024-2028 period vs. the average annual infrastructure investment recorded in 2021-2023, does your "municipality"/"city" expect to increase, decrease or have around the same level of spending on infrastructure investment? (c) For each of the following areas, to what extent, if at all, is access to experts a problem to the delivery of your "municipalities"/"cities" investment programme.*

One striking observation is how previous investments influence perceptions of whether adaptation efforts are adequate. Among municipalities that had invested in adaptation infrastructure from 2021 to 2023, a slightly larger share viewed infrastructure as inadequate than adequate. However, the picture was starkly different for those without prior investments, with about 70% of firms viewing investments as inadequate vs. about 30% seeing them as adequate (Figure 26), underscoring critical shortfalls in adaptation capacity.

Looking ahead, municipalities say they intend to scale up adaptation investments. Of municipalities that did not previously invest in adaptation, about 40 percentage points more of them plan to increase this type of investment in 2024-2028. Municipalities increasingly recognise the urgent need for climate resilience. However, the path ahead is fraught with challenges. A lack of funding remains the most significant obstacle (Figure 27), compounded by regulatory complexities and difficulties in coordinating different groups (stakeholders). The nature of adaptation projects means they require systemic approaches and collaborative planning, making these barriers particularly acute.

Figure 27
Obstacles preventing municipalities from investing in climate adaptation (% of municipalities)



Source: *EIB Municipalities Survey 2024, EIB staff calculations.*
Question: *To what extent is each of the following an obstacle to the implementation of your infrastructure investment activities? Is it a major obstacle, that is, it prevents the "municipality"/"city" from realising a particular project, a minor obstacle, that is, it delays a particular project since it requires additional resources (time, money, approvals, etc.), or not an obstacle at all?*

A lack of access to technical expertise further exacerbates these challenges. Municipalities without prior adaptation investments frequently cite difficulties in finding the right engineering and environmental skills, highlighting a critical bottleneck for projects. However, those with prior investments report fewer difficulties, being 6 to 10 percentage points less likely to identify skill shortages as a major obstacle. This finding underscores the importance of targeted efforts to improve the ability of municipalities to carry out adaptation projects.

Financing structures play a pivotal role in municipalities' ability to close funding gaps. Municipalities that rely on their own resources face have difficulty finding the external funding needed for adaptation projects. By contrast, those receiving capital transfers report more positive financing outcomes, while municipalities with balanced budget structures have fewer issues. This suggests that financing models must be adapted to address the unique funding needs of adaptation projects, ensuring all municipalities can access the resources they need.

Cooperation between firms and municipalities must be encouraged – by working together they can apply their joint strengths to closing the adaptation gap. Public-private partnerships can magnify the impact of adaptation investments, enabling firms to enhance competitiveness while municipalities deliver large-scale, climate-resilient infrastructure. Addressing skill shortages and financial barriers with targeted policies will empower these entities to adopt proactive and context-specific adaptation measures.

Embedding adaptation into long-term planning and risk management frameworks is essential. Firms must transition from reactive to proactive approaches, and municipalities should align their adaptation initiatives with broader sustainability objectives. By harmonising adaptation and mitigation efforts, the European Union can ensure its businesses and cities are well-prepared to navigate the escalating challenges of climate change. This integrated approach not only fortifies resilience, but also establishes a foundation for sustainable growth and competitiveness in an increasingly volatile climate landscape.

Conclusion and policy implications

Europe's journey to a sustainable future presents a dual challenge: advancing the transition to clean energy while limiting carbon emissions. While the power sector has been heavily invested in transforming since the energy shock, the transformation taking place in other economic areas has created leading and laggard firms in all sectors and regions. These differences highlight the need for targeted policies that can enable all parts of the European Union to achieve their climate objectives while enhancing long-term economic resilience. Closing these gaps will not only help Europe reach its climate targets, but also bolster its competitiveness and reduce dependency on volatile energy markets, supporting a more unified industrial landscape across the continent.

Clean energy investments in Europe – particularly in energy-efficient technologies and electrification – remain pivotal to narrowing disparities. Europe has made progress in electrifying transport (such as electric vehicles) and other end-uses of energy (such as heat pump installations). However, investments in hard-to-abate sectors including freight, aviation and shipping remain limited, largely because of technological and financial risks. Across the European Union, it is important to harmonise financing frameworks, reduce market fragmentation and foster cooperation. Those efforts are critical to scaling up innovation and accelerating the development and adoption of technologies to address challenges posed by the transition. Providing financial support and incentives for less mature technologies will enable firms to take advantage of state-of-the-art technologies, reducing inefficiencies and pushing up productivity in all sectors. These efforts will be key to achieving a more integrated and cohesive industrial strategy that combines environmental and economic objectives.

Stricter environmental policies serve as a catalyst that pushes businesses to adopt sustainable practices, which in turn unlock economic benefits. Regulatory stringency drives transformation in all sectors, but targeted incentives are often necessary to maximise impact. As the European Union tightens emissions caps and free carbon allowances become increasingly scarce, it is vital to create an environment that encourages green investment across the economy. This push for transformation affects energy-intensive and non-energy-intensive industries, and the ability of firms to adopt new technologies and reduce their reliance on energy and carbon-emitting activities will play a pivotal role in building resilience. Stringent regulation will help drive the transformation of firms in sectors that continue to rely on less advanced technologies or face operational challenges, while targeted support could help alleviate the financial constraints blocking the transition. These efforts will enhance productivity and promote energy efficiency, particularly in sectors and regions where progress has been slow.

While European firms are making strides in emissions reduction, a significant gap remains in their preparedness for the impact of climate change, leaving many vulnerable to immediate risks like extreme weather. Mitigation efforts driven by strong regulatory and financial incentives dominate, while adaptation investments are weighed down by higher upfront costs, limited immediate returns and skill mismatches. This imbalance is particularly pronounced in resource-constrained small businesses and regions with less supportive regulatory frameworks. To address these issues, adaptation must be integrated into broader clean energy and technology strategies, supported by dedicated funding, tax incentives and targeted training initiatives. Bridging the mitigation-adaptation gap will ensure that firms reduce emissions while also building resilience against climate risks.

References

Allcott, H., & Greenstone, M. (2012). Is there an energy efficiency gap? *Journal of Economic perspectives*, 26(1), 3-28. https://doi.org/10.1257/jep.26.1.3

Barrera-Santana, J., Marrero, G. A., & Ramos-Real, F. J. (2022). Income, energy and the role of energy efficiency governance. *Energy Economics*, 108, 105882. https://doi.org/10.1016/j.eneco.2022.105882

Berkhout, F., Hertin, J., & Gann, D. M. (2006). Learning to adapt: organisational adaptation to climate change impacts. *Climatic change*, 78(1), 135-156. https://doi.org/10.1007/s10584-006-9089-3

Costantini, V., Crespi, F., & Palma, A. (2017). Characterizing the policy mix and its impact on eco-innovation: A patent analysis of energy-efficient technologies. https://doi.org/10.1016/j.respol.2017.02.004

DeCanio, S. J. (1993). Barriers within firms to energy-efficient investments. *Energy policy*, 21(9), 906-914. https://doi.org/10.1016/0301-4215(93)90178-I

Dechezleprêtre, A., & Glachant, M. (2014). Does foreign environmental policy influence domestic innovation? Evidence from the wind industry. *Environmental and Resource Economics*, 58, 391-413. https://doi.org/10.1007/s10640-013-9705-4

Draghi, M. (2024). The Future of European Competitiveness. European Commission. Available at: https://commission.europa.eu/topics/strengthening-european-competitiveness/eu-competitiveness-looking-ahead_en

Ember (2024). European Electricity Review 2024. Available at: https://ember-energy.org/latest-insights/european-electricity-review-2024/

Eurelectric (2025). Electricity in 2024: emissions hit historic low, average prices declined but demand did not pick up - Eurelectric - Powering People. Eurelectric. Available at: https://www.eurelectric.org/news/electricity-in-2024-emissions-hit-historic-low-average-prices-declined-but-demand-did-not-pick-up/

European Chemical Industry Council (CEFIC) (2023). The European Chemical industry Facts and Figures 2023, A vital part of Europe's Future. Available at: https://cefic.org/a-pillar-of-the-european-economy/facts-and-figures-of-the-european-chemical-industry/

European Commission (2024a). EU Climate Action Progress Report 2024. COM (2024) 498 final. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:52024DC0498

European Commission (2024b). Europe's 2040 climate target and path to climate neutrality by 2050 building a sustainable just and prosperous society. SWD 2024 63 final. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:52024DC0063

European Commission (2024c). The EU Taxonomy's uptake on the ground. Available at: https://finance.ec.europa.eu/sustainable-finance/tools-and-standards/eu-taxonomy-sustainable-activities/eu-taxonomys-uptake-ground_en

European Financial Reporting Advisory Group (EFRAG) (2022). Cost-benefit analysis of the First Set of draft European Sustainability Reporting Standards, Final Report. Available at: https://www.efrag.org/sites/default/files/sites/webpublishing/SiteAssets/05%20EFRAGs%20Cover%20Letter%20on%20the%20Cost-benefit%20analysis.pdf

European Investment Bank (EIB) (2024). The scale-up gap: Financial market constraints holding back innovative firms in the European Union. https://doi.org/10.2867/382579

European Investment Bank (EIB) (forthcoming). EIB Municipalities Survey 2024.

Getting to Zero Coalition (2021). A Strategy for the Transition to Zero-Emission Shipping, An analysis of transition pathways, scenarios, and levers for change, UMAS, Getting to Zero Coalition Available at: https://3stepsolutions.s3-accelerate.amazonaws.com/assets/custom/010856/downloads/A-Strategy-for-the-Transition-to-Zero-Emission-Shipping.pdf

Goldman Sachs (2024). Latest Green Revenue & Green Capex shows Significant Growth in Second Year. GS SUSTAIN: EU Taxonomy Monitor, 28 May.

Hagendorn, J.E., Hattemer, B., & Kalantzis, F. (2024). A positive trade-off: Emissions reduction and costs under Phase IV of the Emissions Trading System. EIB Working Paper No. 2024/05. Available at: https://www.eib.org/attachments/lucalli/20240297_economics_working_paper_2024_05_en.pdf

Hallegatte, S., Lecocq, F., & De Perthuis, C. (2011). Designing climate change adaptation policies: an economic framework. *World Bank Policy Research Working Paper*, 5568. Available at: http://documents1.worldbank.org/curated/en/596081468155974532/pdf/WPS5568.pdf

Honma, S., & Hu, J. L. (2018). A meta-stochastic frontier analysis for energy efficiency of regions in Japan. *Journal of Economic Structures*, 7, 1-16. https://doi.org/10.1186/s40008-018-0119-x

International Energy Agency (IEA) (2024a). Clean Energy Market Monitor – November 2024. Available at: https://www.iea.org/reports/clean-energy-market-monitor-november-2024

International Energy Agency (IEA) (2024b). World Energy Investment 2024. Available at: https://www.iea.org/reports/world-energy-investment-2024

International Energy Agency (IEA) (2024c). ETP Clean Energy Technology Guide. Available at: https://www.iea.org/data-and-statistics/data-tools/etp-clean-energy-technology-guide

International Energy Agency (IEA) (2024d). Energy Technology Perspectives 2024. Available at: https://www.iea.org/reports/energy-technology-perspectives-2024

Islam, A. R. M., & Luo, R. H. (2016). Financing constraints in some selected manufacturing firms: An application of stochastic frontier approach. The Journal of Developing Areas, 50(6), 149-160. https://doi.org/10.1353/jda.2016.0130

Kalantzis, F., Khalid, S., Solovyeva, A., & Wolski, M. (2024). Firms' Response to Climate Regulations: Empirical Investigations Based on the European Emissions Trading System, IMF Working Paper No. 2024/135. Available at: https://www.imf.org/-/media/Files/Publications/WP/2024/English/wpiea2024135-print-pdf.ashx

Lin, B., & Huang, C. (2023). Nonlinear relationship between digitization and energy efficiency: Evidence from transnational panel data. Energy, 276, 127601. https://doi.org/10.1016/j.energy.2023.127601

Martin, R., Muûls, M., De Preux, L. B., & Wagner, U. J. (2014). Industry compensation under relocation risk: A firm-level analysis of the EU emissions trading scheme. *American Economic Review*, 104(8), 2482-2508. https://doi.org/10.1257/aer.104.8.2482

Mission Possible Partnership (MPP) (2022). Making 1.5-Aligned Ammonia Possible. An industry-backed, 1.5°C-aligned transition strategy. ETC, RMI, We Mean Business, WEF. Available at: https://staging.missionpossiblepartnership.org/wp-content/uploads/2022/09/Making-1.5-Aligned-Ammonia-possible.pdf

Mission Possible Partnership (MPP) (2023). Making Net-Zero Concrete and Cement Possible. An industry-backed, 1.5°C-aligned transition strategy. ETC, RMI, We Mean Business, WEF. Available at: https://www.missionpossiblepartnership.org/making-net-zero-concrete-and-cement-possible-report/

Niu, Y., Lin, X., Luo, H., Zhang, J., & Lian, Y. (2022). Effects of digitalization on energy efficiency: evidence from Zhejiang Province in China. *Frontiers in energy research*, 10, 847339. https://doi.org/10.3389/fenrg.2022.847339

Palm, J., & Thollander, P. (2010). An interdisciplinary perspective on industrial energy efficiency. *Applied Energy*, 87(10), 3255-3261. https://doi.org/10.1016/j.apenergy.2010.04.019

Porter, M., & Van der Linde, C. (1995). Green and competitive: ending the stalemate. *The dynamics of the eco-efficient economy: environmental regulation and competitive advantage*, 33, 120-134.

Tueske, A., & Lasheras Sancho, M. (forthcoming) Regulatory and economic drivers of firms' energy efficiency investments. EIB Working Paper series.

von der Leyen (2024). Political guidelines for the next European Commission 2024-2029. Available at: https://commission.europa.eu/document/download/e6cd4328-673c-4e7a-8683-f63ffb2cf648_en?filename=Political%20Guidelines%202024-2029_EN.pdf

World Economic Forum (WEF) (2023). Net-Zero Industry Tracker 2023 Edition. Available at: https://www3.weforum.org/docs/WEF_Net_Zero_Tracker_2023_REPORT.pdf